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The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Reflections on the Welding Symposium.—II

We referred in our last issue to the attitude of the insuring and classification societies in this country to welding, and in this connection the Paper by Dr. Dorey, of Lloyd's, is of especial interest. In speaking of welding *versus* casting, he says that in theory the reduction in scantlings could be inversely proportional to the ratio of the elastic moduli of mild steel and cast iron. "There is, however, the factor of rigidity to be taken into account, and in this respect no form of fabricated structure could be better than that obtained in a sound, well-designed casting." Dr. Dorey then adds: "In the circumstances it is an obvious conclusion that the main advantage to be derived from welded engine entablatures is economic rather than scientific." In marine-engine work, since the ship is not a rigid foundation, the effects of vibration must be specially watched, and altogether the conclusion is reached that, "It is apparent, however, that the question of rigidity of structure is one which will require considerable attention."

Other authors (*i.e.*, Mr. C. H. Stevens, for example) refer to the better modulus of elasticity of steel compared with cast iron, and it is clear that before we can really consider this matter, some generally-accepted method must be adopted of determining the modulus of elasticity of cast iron. At the present time, the available data are scanty and confused, and this lies at the root of the difficulty of the scientific design of iron castings.

The Symposium was remarkable for the number and variety of the Papers presented from so many parts of the world. The policy for the foundry industry should, it is suggested, be as follows. Every possible advantage should be taken inside the industry of the facilities offered by the welding process, for the repair of castings, and even for the fabrication of cast parts. The metallurgy of the process should be studied with the object of making sound and acceptable welds which are better and stronger in themselves than the original metal. Furthermore, the industry should do all it possibly can to improve the casting as such, in design, in properties and in structure, and to cheapen its production. The welding industry is new. If the casting process had been discovered as recently, and had had the intensive investigation which the welding process has received, it might have been, as it can yet be, in a much stronger position to meet its rival.

The Sheffield Conference.—I

Increased industrial activity is being reflected in the organisation of the thirty-second Annual Conference of the Institute of British Foundrymen, to be held in Sheffield from July 2 to July 5. As will be seen from the programme, which is presented elsewhere in this issue, every section—technical, social and "plant visitations," to use an Americanism—is of an exceptionally interesting character. If we have any criticism at all to make, it is that there does not appear to be sufficient time for all the various speeches of welcome; and that consequently the proceedings of the first session may be somewhat rushed. We hope that our fears are ill-founded, as the whole industry is looking forward to the delivering by Sir William Larke, K.B.E., of the first Edward Williams Lecture on "Man and Metal."

The programme of technical Papers is unquestionably brilliant, and those entering the category of steel castings include contributions from such well-known metallurgists and foundry experts as Dr. W. H. Hatfield (who, by the time the meeting takes place, will be a Fellow of the Royal Society), Prof. J. H. Andrew, Mr. George Batty (who will present the American Exchange Paper) and Mr. W. Machin and Mr. Oldham conjointly. The last-named are associated with the Barrow foundry of Vickers-Armstrong. Dr. T. Swinden, in conjunction with Mr. G. R. Bolsover, is making a very important contribution to the study of ingot-mould practice, and will prove that recently-published costs of iron casting consumption per ton of steel made were

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somewhat extravagant. The French Exchange Paper is to be given by Mr. Henri Fabre, whose published work we have followed with interest for some years; it covers the very important field of "Loam Moulding." Automobile castings are being dealt with by Mr. W. A. Geisler, of whose competence we have knowledge by very pleasant personal contact. The Institute has been fortunate in procuring Mr. W. J. Rees, the head of the Refractory Department of Sheffield University, to deal with "Refractories for Foundry Use," as he is the premier expert on the subject. Sand in non-ferrous foundry practice has been rather taken for granted in the past, and it will be interesting to hear what Mr. F. Howitt has to reveal. He has followed the work done in iron and steel foundries and has applied the results to non-ferrous foundry practice. In view of the negotiations now proceeding for the creation of new standard tests in cast iron of the higher qualities, Mr. G. L. Harbach's Paper on the "Relationship in Cast Iron Test Results" is especially appropriate. No better selection of Papers has ever been arranged for discussion.

A New Vitreous Enamel Factory

The Ferro Enamelling Company (England), Limited, has established at Wombourne, near Wolverhampton, a new factory for the manufacture of vitreous enamel, enamelling plant and equipment. It is expected to be in full production in about three months' time. Mr. William Marshall, one of the pioneers of the wet process of vitreous enamelling, is the managing director, and the new factory is to make the frits which hitherto Mr. Marshall has imported either from Rotterdam or Cleveland, Ohio. Wombourne has been chosen as a site because of the cleanliness of its atmosphere.

South African Iron and Steel Developments

Full details of the South African Iron & Steel Industrial Corporation's development scheme were given in a speech by the South African Minister of Commerce and Industries when moving the second reading of a Bill to increase the capital of the Corporation by £1,500,000. A sum of £364,000 had been spent on small items, including an extension of the finishing bays £48,000, foundry £35,000, inactive mixer £32,000, plant and machinery for workshops £25,000, and sundry equipment £18,000, while the balance of £1,136,000 would be spent on a cogging mill £220,000, soaking pits and casting and stripping accommodation £145,000, continuous reheating furnace £60,000, gas-producing plant £60,000, rolling stock and workshops £67,000, plate mill £350,000, extra blast-furnace stack £200,000. The objects to be attained by this expenditure are two-fold. Firstly, to obtain as large a share of the additional business now available through the boom in mining as possible; and, secondly, it is hoped to secure a better balance between the production capacities of the various departments. The Minister declared that a recent survey in the Witwatersrand area had disclosed a monthly demand for products of the steelworks of over 22,000 tons. Since the original works were planned on an estimated cost of £5,500,000, conditions in the Union had undergone a vast change and it was now possible to visualise a steelworks of far larger dimensions than was originally anticipated. The Bill passed through all its stages in the Assembly.

Tensile Strength of Cast Iron

According to a Paper by G. MEYERSBERG in Rev. Mét., the true strength of cast iron is not obtained in the tensile test since plastic deformation alters the dimension of the test-piece before fracture occurs. By breaking test-pieces with notches of gradually increasing depth, increasing tensile strengths are obtained. Extrapolation then gives the stress at which the metal would break if 100 per cent. reduction of area occurred at the point of fracture.

To Present American Exchange Paper

Mr. Batty, who is to present on behalf of the American Foundrymen's Association a Paper to the forthcoming conference of the Institute of British Foundrymen, was born in Sheffield, the city where the congress is to be held. After completing his earlier education, he attended Sheffield University, specialising in the department of applied science, at which time he became interested in the early developments in electric furnace melting of metals.

Entering the field of commercial production in 1909, Mr. Batty was employed as steelmaker for the Darwin group of companies at Sheffield, remaining with this group until 1914, when he accepted a similar position with John Kenyon & Company, Limited, another Sheffield firm.

MR. GEORGE BATTY.

In 1919 he was appointed works manager of James Fairley & Sons, of the same city. After spending the year of 1920 in the United States as a consultant, Mr. Batty was technical director of the National Steel Foundry of Leven, Scotland, in 1923-27.

In 1927 Mr. Batty again returned to America as a consultant, and in 1928 accepted the position of technical director of the newly-organised Steel Castings Development Bureau. Early in 1935 he resigned this latter position and accepted the position of technical director with the Crucible Steel Casting Company, Lansdowne, Pa., U.S.A. Mr. Batty has written extensively for the technical Press and scientific societies on subjects of steelmaking and problems encountered in the production of steel castings. Mr. Batty, who is a member of the American Foundrymen's Association, being a director at the present time, and the American Society for Metals, has chosen for his subject "The Influence of Temperature Gradients on the Production of Steel Castings."

Reconditioning Pickling Solutions

In the pickling of steel products, the sulphuric acid weakens until, when spent, the solution consists of very weak acid and the ferrous-sulphate formed from chemical combination of the consumed acid with the steel. For many years the disposal of this waste solution has been a serious problem with most industrial plants. MR. S. F. SPANGLER, of the Chemical Construction Corporation, New York, describes, in "The Iron Age," the method developed by this concern.

Publication Received

Coventry. Its Situation and Industrial Advantages. Issued by the Development Department, Council House, Coventry.

Too many publications of this character are ponderous, due to the insertion of advertising matter and consequent over-elaboration. Coventry has not made this mistake, and the result is a readable, convincing brochure, which gives most of the essential information required by a manufacturer looking for a site on which to establish a factory, except the level of the local rates and their tendency. That they cannot be overwhelming is shown by the rapid increase in the importance of Coventry as a manufacturing centre during recent years. Though it is limited to twenty pages, all the essentials are dealt with, such as electricity, gas and water supply, transport (both internal and external), canals and so forth. We commend those in search of factory sites to procure this small booklet.

Patternmakers' Annual Report

The 63rd annual report of the United Patternmakers' Society is the best for some years. It shows a gain on the trade union side of £5,502, the funds now amounting to £48,747. Mr. Alan Findlay, the secretary, attributes this to the steady payment of contributions, but points out that members are still £2,670 in arreas. The patternmakers between 1921 and 1932 had a gross income of £620,403 and a gross expenditure of £779,675, showing a loss for the period of £159,271, which illustrates how employment impoverished the unions in the post-war decade. The average weekly wage is given by the general secretary as £3 2s. 2d., an increase of 8d. compared with the previous year. The total membership of 10,085 is much the same as last year, but in each of the three previous years there were decreases. There were 549 new members admitted and 381 excluded, which the executive think might have been avoided by better branch organisation. Mr. Findlay warns the members that the superannuation reserve fund will disappear in four years unless the present policy is altered. Last year superannuation cost £12,010, against an income of £5,776. The auditors endorse his opinion, which no doubt will be considered by the branches during the year.

Carron Jubilee Gifts

Carron Company, having had under consideration the different decisions of the various employers' organisations of which the company is a member as to how the Silver Jubilee of His Majesty the King might most appropriately be recognised, has determined to mark the occasion by making the following donations:—To King George's Jubilee Trust, £500; Falkirk and District Royal Infirmary, £250; Edinburgh Royal Infirmary, £100; Glasgow Royal Infirmary, £100; Glasgow Western Infirmary, £100; Glasgow Victoria Infirmary, £100. The position of the Carron Company was somewhat difficult because of the fact that it is associated in membership with so many different organisations—ironfounding, shipping, coal mining, pig-iron production, etc. Certain of these organisations had recommended that so far as granting a special payment to workmen in respect of the Jubilee holiday was concerned no action should be taken, whilst others had taken the opposite view. In the circumstances the directors felt that to make a payment to all employees would be tantamount to breaking faith with certain of the associations with which the company is connected, while it was also felt that to make the payment to certain of the employees would be unfair to the others. The directors were extremely anxious to mark in some appropriate way the Silver Jubilee of His Majesty, and after considering the matter, came to the decision that the most suitable and most acceptable way out of the difficulty was to make the donations to the charitable organisations and institutions named.

FERROUS LIGHT CASTINGS, LIMITED, in view of increasing demand, have undertaken a comprehensive scheme of extensions, the first part of which is now complete.

The Iron and Steel Institute

ANNUAL MEETING IN LONDON

The Annual Meeting of the Iron and Steel Institute was opened on Wednesday, May 1, at the Institution of Civil Engineers, Great George Street, Westminster. Mr. W. R. Lysaght, J.P., C.B.E. (retiring President), occupied the chair at the outset.

Report of Council

The Council of the Institute, in their report, state that during the past year 91 new members and 19 associates were elected; seven associates were transferred to membership, and 15 members were reinstated. Fifty members resigned their membership during the year. The total membership of the Institute on the register on December 31, 1934, was accordingly as follows:—Patron, 1; honorary members, 18; life members, 74; ordinary members, 1,770; associates, 55—a total of 1,918.

Referring to the deaths of 30 members during the year, the Council place on record an expression of their deep regret at the loss of their former colleagues, Mr. E. H. Saniter, Mr. A. Pourcel and Mr. W. G. Gray. Mr. Saniter was one of the older members of the Institute, having joined in 1892; he became a member of Council in 1921, and was elected a Vice-President in 1927. Mr. Pourcel's association with the Institute was even longer; he became a member in 1879 and was elected an Honorary Vice-President in 1918. Both Mr. Saniter and Mr. Pourcel were Bessemer Gold Medallists of the Institute. Mr. Gray became a member of the Institute in 1917, and was elected a member of Council in 1927.

Finance.—The income of the general fund during 1934 was £7,714 15s. 11d., and the expenditure £9,902 8s. 7d., the result being an excess of expenditure over income of £2,187 12s. 8d. The receipts of the special appeal fund during the year amounted to £2,032 7s., and this figure has been taken into the accounts, leaving a net debit balance of £115 5s. 8d. to be carried to the balance-sheet.

Changes on the Council.—Mr. James Henderson was elected honorary treasurer to succeed Sir Harold Carpenter, F.R.S., who resigned this office as on October 1, 1934, on his nomination as President-Elect. Monsieur Léon Greiner (Seraing) and Monsieur Aloyse Meyer (Luxemburg) were elected Honorary Vice-Presidents of the Institute on the occasion of the autumn meeting in Belgium and Luxemburg. Lieut.-Col. Sir Maurice H. L. Bell, Bt., C.M.G., was nominated an Honorary Vice-President on November 8, 1934. In order to fill the vacancies caused by the nomination of Mr. James Henderson as honorary treasurer and by the death of Mr. E. H. Saniter, Dr. W. H. Hatfield and Sir William Larke, K.B.E., were nominated Vice-Presidents. The election of members of Council to fill the three vacancies was deferred.

In accordance with Bye-law 10, the names of the following Vice-Presidents and members of Council were announced at the autumn meeting as being due to retire at the annual meeting in 1935:—*Vice Presidents*: Mr. J. Henderson, the Hon. Roland D. Kitson, D.S.O., and Dr. C. H. Desch, F.R.S. *Members of Council*: Mr. J. E. James, Dr. W. H. Hatfield, Dr. A. McCance, Mr. P. B. Brown and Mr. A. O. Peech.

Mr. Henderson and Dr. Hatfield having been elected honorary treasurer and Vice-President respectively, Mr. Arthur Dorman (Vice-President) and Mr. H. Leighton Davies become due to retire in their places. No other members having been nominated up to one month previous to the annual meeting, the retiring members were presented for re-election.

Andrew Carnegie Research Scholarships.—Grants were made by the Council in 1934 to the following candidates:—

M. Alexander (University College, Swansea), £100 for a further study of the influence of gases on the position of blowholes in steel ingots.

D. G. Davies (University College, Swansea), £100 for a further study of the influence of gases on the position of blowholes in steel ingots.

R. B. Mears (Cambridge University), £100 for a study of the effect of composition on the corrosion velocity and corrosion probability of steel.

T. Raine (Sheffield University), £100 for an investigation of the determination of oxygen in steel.

SIR H. C. H. CARPENTER, F.R.S.
(President of the Iron and Steel Institute).

E. M. Trent (Sheffield University), £100 to investigate the manufacture of clean steel.

H. Wentrup (Technical High School, Berlin), £100 in aid of an investigation of the equilibrium $Mn + FeS \rightleftharpoons MnS + Fe$ in iron melts containing carbon and the influence of silicon and phosphorus upon it.

L. E. Adams (College of Technology, Manchester), £50 for a study of the effect of torsional overstrain on the physical properties of steels suitable for helical springs.

C. L. Shapiro (Harvard University), £50 in aid of his investigation of the physical and chemical properties of a constituent obtained by special heat-treatment of spheroidised steels.

Induction of New President

MR. W. R. LYSAGHT (retiring President) said that it was with regret that he reached the end of his two years as President of the Institute. He had enjoyed his term of office very much indeed. He was being succeeded as President by Sir Harold Carpenter, a most distinguished man who would conduct the duties of President most ably. It was of interest to note that Sir Harold was a great-great-grandson of Henry Cort, who, as some of the members might recall, started puddling some 150 years ago, and so well did he do it that the methods then invented were still very largely in use.

Mr. Lysaght then vacated the chair, which was taken by the new President, Sir Harold Carpenter.

MR. F. W. HARBORD, C.B.E. (Past-President), said that it was with the very greatest pleasure that he proposed a vote of thanks to Mr. Lysaght for his valuable services in the chair. Few Presidents had had such a long connection with the iron and steel industry and such a wide experience on the technical and on the commercial side as Mr. Lysaght. In addition to his very many other qualifications, the retiring president had that gift of the gods, a keen sense of humour, of which he had given evidence during his presidency.

The vote of thanks was carried with acclamation.

MR. W. R. LYSAGHT said he was very grateful that the vote of thanks had been proposed by Mr. Harbord. Mr. Harbord and himself were two of the oldest members of the Institute; he remembered Mr. Harbord nearly fifty years ago in Wolverhampton as one of the pioneers of the basic process.

THE PRESIDENT said it was a great privilege to him to follow Mr. Lysaght in the presidential chair. He would not say that Mr. Lysaght had made it too difficult for anyone else to follow him, but the best tribute he could pay to Mr. Lysaght's success as President was that he was finding it very difficult to follow him. He would like to thank Mr. Lysaght for the words he had used in introducing him to the meeting, and to thank his colleagues on the Council for the great honour which they had done him in electing him to the Presidency.

Presentation of Bessemer Gold Medal

THE PRESIDENT said they had hoped to have with them that day His Excellency the French Ambassador, but unfortunately a previous engagement had prevented his attendance. The Institute was glad to welcome, however, M. du Halgouet, the French Commercial Attaché. The Bessemer Gold Medal had been awarded this year to Prof. A. M. Portevin, Director of the Institut de Soudure Autogène, Professor at the Ecole Supérieure de Fonderie, and at the Ecole Centrale des Arts et Manufactures, Paris. Prof. Portevin obtained a Carnegie Scholarship in 1907, and the results of his investigation, which dealt with the constitution of special ternary steels, were published in the Carnegie Scholarship Memoirs in 1909. For this work he was awarded the Carnegie Gold Medal. He was elected a member of the Institute in 1910. His early Papers were concerned with a wide variety of problems in physical metallurgy, mostly connected, more or less directly, with the heat-treatment of steel. His brilliant work in collaboration with A. M. Garvin, on the effect of rapid cooling on the temperature of the transformation in steel, was unquestionably one of the greatest steps ever made towards an understanding of the effect of heat-treatment, and of the function of alloying elements in steel. Since that Paper was published (in 1919), he had continued to interest himself in the subject, and almost every year he had made further valuable contributions to it. Most of those Papers had been published in the Revue de Métallurgie, which owed a great debt to Prof. Portevin, because, in addition to being one of its most valued contributors, he was its general secretary and Vice-President of its

Editorial Committee. He was universally regarded as one of the greatest living authorities on heat-treatment. Although heat-treatment had always been, he thought, Prof. Portevin's favourite field of research, he had carried out many valuable investigations on other subjects. Up to the present time there had been 67 awards of the Bessemer Medal, and 25 of those had been made to distinguished foreign metallurgists. No less than eight of those were Frenchmen. Prof. Portevin accordingly became the ninth representative of that illustrious band of workers. It would, he thought, be conceded on all hands that he was worthy to take his place with them.

The President then presented the Bessemer Gold Medal to Prof. Portevin.

Prof. Portevin, who spoke in French, thanked His Excellency M. du Halgouet, the representative of the French Ambassador, for being good enough to be present. He was happy to express to the President, to the members of the Council and to all his colleagues in the Institute his profound thanks for the supreme distinction conferred upon him, which would remain the honour and the crown of his career. Not only was there attached to it the great name of Bessemer but also it had been presented in the past to the most illustrious metallurgist of the entire world.

Presidential Address

Alloys—Old and New

Sir Harold Carpenter then delivered his Presidential Address, from which the following extracts are taken:—

The word "alloy" is much in use to-day, and there is no doubt that in its most popular sense it implies something superior to a plain metal. Originally, it meant the opposite to this, and scientifically it has always meant a metal containing more than one constituent, without regard to whether the effect of the other constituent is beneficial or otherwise.

When the prevailing ideas about metals were dominated by the conception of abstract value, alloying was regarded mainly as a device for debasing the precious metals. To-day, when ideas about metals are principally concerned with the use to which they may be put, alloying is the most important method available for securing desirable properties. Thus, as the position of metals in our affairs has altered, so has the popular meaning of the term alloy. In its scientific sense the term takes no account of the reasons for the presence of the other elements, and this may be considered satisfactory, but neither does it take account of whether the mixture is intentional or accidental, and this is not so satisfactory, for it fails to distinguish between an alloy and a metal.

Scientifically a pure metal is a metallic element with a purity of 100 per cent. If everything else is an alloy, then there is no practical distinction between a metal and an alloy, for, although this purity has been closely approached in many metals, it has never been attained. With the knowledge available to-day, it is obviously impossible to restrict the term alloy to metals containing other than the basis metal, for extremely small amounts are known to have pronounced effects on their properties. Thus, if we are to make any distinction between metals at present available and alloys, it appears that we must take account of other factors besides chemical composition. I suggest, therefore, that while metal in its general sense means all metallic substances, in its particular sense it should be taken to mean an elementary metal in the condition of purity which can at present be attained. A pure metal would then mean one whose purity approached 100 per cent., while an impure metal would imply one of a lower degree of purity which would be more highly purified if the cost was justified. An alloy in its scientific sense may include everything except a pure metal, but in its general sense it should signify a metal to which other elements are added or in which they are allowed to remain in order to obtain certain desirable properties at an economic price. In this address, except where otherwise indicated, I shall use this term to denote a metallic substance made by the intentional admixture of two or more elements with the object of obtaining properties not available in commercially pure metals, and shall thus be able to distinguish between metals, impure metals, alloys, and impure alloys.

Proceeding, Sir Harold gave a sketch of the history of alloys, and then went on to a consideration of the study of alloys, saying that, although many carefully-planned and accurately-executed investigations have been performed on alloys, the subject as a whole cannot be said to have been systematically studied. This is no reflection on those who have taken part in this study, for it could not, under any circumstances, have followed a preordained programme. To begin such a systematic study, pure metals would be required in the first place. Then from these, binary, ternary and more complex alloys would have to be made and studied with full knowledge of the effects of casting conditions, working, thermal treatment, etc., etc. Actually alloys have been made and studied by using impure metals and in ignorance of some of the effects of casting conditions, heat and mechanical treatment. While the study of these has been going on other investigations have been pursued in order to discover how to eliminate impurities so that in the future purer alloys may be made and studied. Then from other investigations experience has been gained that has increased our knowledge about casting, working, thermal treatment and methods used in studying properties. This has been utilised in later investigations either on the same or different alloys. From time to time phenomena have been discovered which have caused an intensive application of research on particular lines, and it has been shown that work previously done in ignorance of these phenomena cannot be regarded as reliable. Considered as a whole, the study of alloys has followed a very devious route, but it has always proceeded in the same general direction, viz., towards a fuller comprehension of the subject and an ability to produce a greater variety of useful and reliable alloys.

At the present time our knowledge is founded on what may be described as the characteristic nature of each individual alloy in the condition in which it will be used. To this we relate its properties on the one hand and its previous treatment on the other. This nature is determined first of all by its composition. What are the properties of the basis metal or metals? What are the effects of the subsidiary elements present as impurities or added by design? Next comes the question of constitution. What sort of crystals are formed by the atoms of the elements present? Are all the added elements in solid solution in the basis metal, and what effect do they have on its properties? Are other constituents formed; if so, of what kind are they, and what are their properties? A third important factor is structure, *i.e.*, the arrangement of the crystals of the constituents in the solid alloy, and the fourth is condition, in which may be included the effects of cold-working, inclusions, forging defects, quenching cracks, and casting defects, such as blowholes, contraction cavities, hot-tears, etc.

The characteristic nature of the alloy as it goes into service is the basis of our study. We consider its previous treatment and its behaviour in use in relation to this, and thereby achieve a more accurate correlation between treatment and properties than would be possible if these had to be directly connected. When we know that a certain result may be obtained by a particular sequence of treatments, we utilise this knowledge, but we are not satisfied until we know why this sequence gives that particular result. We are then in a position to modify this treatment so as to secure even better results, and, furthermore, we can often produce other alloys that will be improved by similar treatments.

The Composition of Alloys

The study of alloys would be greatly simplified if it were possible to consider separately each of the factors that constitute its nature in relation to each stage in its treatment and each of its properties. Actually, however, nature, treatment and properties are so intimately connected that they must be considered together. Thus, although various headings may be selected to facilitate description, it is impossible to adhere strictly to this plan.

When composition is considered alone without regard to treatment, its importance is seen to vary greatly with the properties we have in mind. In the case of electrical conductivity, composition is all-important, and in preparing conductivity copper or aluminium, the highest attainable purity is sought. Where it is technically impossible to eliminate all the impurities, and there is some choice as to which impurity should be left, constitution is important, because elements that do not enter into solid solution have less effect in decreasing the conductivity than those that do. Thus, in the manufacture of high-conductivity copper, the object is to eliminate other impurities by means of oxygen while leaving as little of this element as possible in the metal. If mechanical strength has to be taken into account in addition to conductivity, other aspects of the composition become important, and so does treatment. Considerable improvement in strength may be effected by cold-working without serious diminution of the conductivity of copper or aluminium, but when further increase in strength is necessary, recourse must be had to some other element that raises the strength as much as possible while decreasing the conductivity to a minimum extent. Thus silicon or cadmium is added to copper to increase its strength in the cold-worked condition, and silicon, magnesium, and manganese are added to aluminium to increase its strength in the heat-treated condition.

For magnetic properties also composition is a most important factor, but treatment as affecting condition and constitution must also be considered. When high magnetic permeability is required, selection is restricted to iron in the purest condition available, an iron alloy containing about 4 per cent. of silicon, and iron-nickel alloys containing about 50 or 70 per cent. of nickel. The permeability of all these metals is best when they are free from the effects of cold-working, and when they have been given the correct heat-treatment, which consists of annealing the first two and of cooling the iron-nickel alloys at a controlled rate. Despite the effect of treatment, however, the composition is the controlling factor. When high remanent magnetism and high coercive force are required, quite different alloys are used, and treatment becomes of even greater importance. The properties of the original carbon magnet steels depend just as much on the fact that they are quenched so as to retain them in the martensitic condition as on their high carbon content. Similarly, with the tungsten, chromium and cobalt steels subsequently introduced, heat-treatment is important because of its effect on constitution, and although treatment is not so essential in developing the properties of the new iron-nickel-aluminium magnet alloys, it has, nevertheless, an important influence.

Chemical properties as exhibited by resistance to electro-chemical corrosion and direct oxidation also depend primarily on composition. These influence many uses of metals, for whenever a metal is employed without a surface coating of some other metal, some compound, paint or enamel, it may be said to be thus employed because it resists satisfactorily the conditions to which it is exposed. The environments in which metals are used are very varied, and a large number of them may be said to give satisfactory service in one way or another. The metals, however, in which resistance to oxidation and corrosion are important properties are in general those that are used where others would fail.

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Some of the metals used in this way are pure metals, *e.g.*, lead, copper, nickel or aluminium, while others are alloys that owe their high corrosion resistance to the presence of certain elements.

Although numerous metals are used under conditions where some resistance to corrosion is required, the number of alloys that are specifically employed because of this property is not large. The basis metals of these alloys are iron, copper and nickel, and the added elements are nickel, chromium, aluminium, silicon and tin. As these owe their resistance to corrosion to their capacity to form continuous adherent protective films, and confer this property on the metals to which they are added, their effect depends on their form of occurrence. The second metal must always be held in solid solution by the first. The heat- and corrosion-resisting non-ferrous alloys, *e.g.*, aluminium-bronze, aluminium-brass, nickel-copper alloys, nickel-chromium alloys and nickel-chromium-iron alloys are all solid solutions, while in ferrous alloys it is only that proportion of the protective element that is dissolved in the iron that is effective.

As chromium and iron form a continuous series of solid solutions, all the chromium would be available to protect the iron if no carbon were present. But when it is present, carbides of high chromium content are formed, and the corrosion resistance of the alloy is appreciably decreased if these are permitted to separate from solution. Thus constitution has a pronounced effect on the resistance of such steels, and must be carefully controlled. There are four general types of these steels—the pearlitic, martensitic, austenitic and ferritic. Of these, the first, which is represented by stainless iron, may be regarded as an attempt to combine a fairly high resistance to corrosion with properties similar to those of high-tensile structural steels. It may be used in the annealed, normalised, or quenched and tempered condition, and, although the carbon, and therefore some of the chromium, is not retained in solid solution in some of the conditions of its use, sufficient chromium remains dissolved to impart a moderately high resistance to corrosion. In the martensitic type, both carbon and chromium are retained in solution by heating to a temperature sufficiently high to dissolve the carbide, quenching as rapidly as possible, and tempering at a temperature below that at which carbide begins to form. If the quenching temperature is lowered, the rate of cooling decreased, or the tempering temperature raised, some chromium carbide is formed, less chromium remains to protect the iron, and the corrosion resistance is diminished.

The other two types of stainless steel are conspicuously different from steels in general, in that they do not undergo the ordinary reversible changes on heating and cooling, and do not respond to treatments like normalising, hardening and tempering. Austenitic steels were used before austenitic stainless steel was developed. Thus Hadfield's manganese steel proved invaluable for numerous purposes, because of the toughness of the austenite retained by quenching, and its tendency to transform to hard martensite on any surface subjected to wear and abrasion. Austenitic nickel steel was used because of its non-magnetic and corrosion-resisting properties. Nevertheless, the introduction of the austenitic nickel-chromium steels represents a new development in steel metallurgy, because of their high resistance to corrosion, suitability for hot- and cold-working, and insusceptibility to heat-treatment in the usual sense. The ferritic stainless steels were the first steels of this type to be used.

The austenitic stainless steels illustrate some interesting aspects of the relations between composition, treatment, constitution and properties. Nickel is one of the elements that increase the range of stability of austenite, and about 28 per cent. is required to retain this constituent down to atmospheric temperatures. Chromium, however, is one of the elements that decrease the range of stability of austenite, and in the absence of carbon and nickel, no austenite is formed in iron-chromium alloys containing more than 14 per cent. of chromium. Yet, when this element is added along with nickel, it supplements its effect in retaining austenite down to atmospheric temperatures, and the best-known types of such steels contain chromium and nickel in the proportions 18/8, 15/11 and 20/7. The constitutional effect of chromium in these cases does not depend on its influence on the relations between γ- and α-iron under equilibrium conditions. It rests on its action in retarding transformations. An alloy containing 18 per cent. of chromium, 8 per cent. of nickel and 74 per cent. of iron solidifies as a mixture of ferrite and austenite. During cooling the ferrite changes to austenite above 1,300 deg. C. in the same way that δ- changes to γ-iron in iron-carbon alloys. Under equilibrium conditions ferrite should begin to re-form at 850 deg. C. and continue to below 300 deg. C., when the alloy would consist mainly of this constituent. But at ordinary rates of cooling from 900 to 500 deg. C., ferrite does not form at all, and the sluggishness of the alloy prevents it from forming at lower temperatures. Thus, although chromium decreases the range of stability of austenite under equilibrium conditions, in nickel-chromium steels of suitable nickel content it promotes the retention of austenite at atmospheric temperature by inhibiting the changes that should take place on cooling below 850 deg. C.

The solubility of carbon in the nickel-chromium austenite of stainless steels is very small. According to Aborn and Bain, it decreases from 0.4 per cent. at 1,200 deg. C. to 0.03 per cent. at 800 deg. C., and becomes less than this at lower temperatures. The actual carbon content of these steels is generally below 0.1 per cent., but it is never below 0.03 per cent., and consequently, under equilibrium conditions, a carbide phase should be present below 800 deg. C. Under ordinary conditions of cooling, however, the formation of carbide in the range 800 to 400 deg. C. is prevented, and it cannot take place below this temperature. Thus, the carbon is retained in solid solution and assists in stabilising the austenite. But in operations that involve heating at temperatures above 450 deg. C., diffusion of carbon can proceed at an appreciable rate, and any carbon in excess may separate from solution and form carbide. This contains a considerable amount of chromium, and as the rate of its diffusion is much slower than that of carbon, the carbide is formed from chromium drawn from the vicinity of the crystal boundaries. The chromium content is thus decreased, and corrosion is liable to occur there. It is on this that the intergranular corrosion of stainless steels depends. The technique of controlling or preventing it has since been developed.

It is evident from the foregoing that the corrosion resistance of stainless steel depends (1) on the presence of chromium; (2) on this element being dissolved in the iron, and (3) on the presence of a minimum amount of carbide. Their mechanical properties depend, however, on their constitution rather than their composition, and pearlitic, martensitic, austenitic and ferritic chromium or nickel-chromium steels resemble other steels of similar constitution more than they resemble each other.

Constitution and Structure

Whereas the nature of the electrical, magnetic or chemical properties required practically determines the composition of the alloy to be used, when mechanical properties only have to be considered, there is usually a choice of several alloys which will give the required results.

The study of the constitution and structure of alloys is based on their equilibrium diagrams, and, neglecting changes in the solid state, most of the diagrams that apply to the useful ranges of composition of industrial binary alloys may be classified as follows:—

(1) Each metal is soluble in the other to a limited extent when solid, and alloys of intermediate composition consist of a mixture of these two solid solutions. Examples of this type are the lead-antimony, lead-tin and nickel-chromium systems. The aluminium-silicon system must also be included in this class, although there is no solid solubility of aluminium in silicon.

(2) The two metals are soluble in each other in all proportions when solid. The copper-nickel, iron-chromium and iron-vanadium alloys are examples of this type, but the iron-nickel, iron-cobalt and iron-manganese alloys may also be included, although the crystal structure of the solid solution changes with the composition. The two face-centred cubic metals copper and nickel form a continuous series of solid solutions with face-centred cubic lattices. The body-centred metals chromium and vanadium form a continuous series of solid solutions with body-centred iron, but when the face-centred metals nickel and cobalt are alloyed with iron, solid solution with a body-centred lattice are formed at the iron end, while throughout the rest of the system face-centred solid solutions are produced. In the iron-manganese system, however, in addition to the body-centred solid solution formed at the iron end, and the face-centred solid solution at higher manganese contents, there is a third solid solution formed when the manganese exceeds 70 per cent., viz., one based on the tetragonal lattice of γ-manganese. In these systems of alloys between iron and nickel, cobalt and manganese, respectively, solid solutions based on α-iron, γ-iron, and the other metal occur, but as the lattices of nickel and cobalt are the same as that of γ-iron there are only two different solid solutions, whereas owing to the difference between γ-iron and γ-manganese there are three different constituents in that system.

(3) At the useful end of the system the added element is soluble to some extent in the basis metal, and when this limit is exceeded a eutectic between the solid solution and an intermediate constituent appears. Examples of this type are the alloys of iron with carbon, molybdenum, tungsten and silicon and those of aluminium with copper, iron, manganese and magnesium.

(4) A series of intermediate constituents is formed as in the alloys of copper with aluminium, zinc, tin and silicon or in those of iron with aluminium.

Continuing, the President dealt with the constituents and structures of alloys and then went on to a consideration of the transformations in solid alloys.

One of the most recently discovered changes is that which involves rearrangement of the atoms in a solid solution. The transformation in β brass between 453 deg. C. and 470 deg. C. which has been the subject of so much controversy is now considered to be due to such a rearrangement, as a result of which an ordered distribution of two kinds of atoms is produced. Thus above the transformation range copper and zinc atoms are distributed at random among the lattice points of the body-centred lattice, while below it each kind of atom occupies all the lattice points on one of the interpenetrating simple-cubic lattices of which the body-centred lattice is made up.

Similar changes from disordered to ordered distribution occur in copper-gold and iron-aluminium alloys. Copper and gold form a continuous series of primary solid solutions, and above 420 deg. C. the two kinds of atoms are distributed at random among the lattice points of the face-centred cubic lattice. With moderately rapid cooling this random distribution persists down to atmospheric temperature, but during slow cooling or subsequent reheating in the appropriate range of temperature, ordered structures result. One of the constituents thus produced contains 75 atomic per cent. of copper and 25 atomic per cent. of gold, and may therefore be represented by the formula Cu_3Au. The other contains equal atomic proportions of gold and copper, and may be represented by the formula CuAu. By the substitution of gold for copper or copper for gold atoms the β constituent (Cu_3Au) may vary in the composition from 17.5 to 35.5 atomic per cent. of gold,

according to Haughton and Payne, while the δ constituent (CuAu) may vary in composition from 36.5 to 71 per cent. of gold. In Cu_3Au the gold atoms occupy the corner positions in the face-centred cubic lattice and the copper atoms the face-centred positions. In CuAu a face-centred tetragonal lattice is formed with gold atoms in the corner positions and in two of the face-centred positions, while the copper atoms occupy the remaining four face-centred positions.

In copper-gold alloys cooled rapidly from above 500 deg. C. the two kinds of atoms are distributed at random on a face-centred cubic lattice, and the properties vary with composition in the manner characteristic of primary solid solutions. The electrical resistance and hardness rise to a maximum at 55 atomic per cent. of gold and are related to composition by smooth curves. In slowly-cooled alloys, when β and δ are formed, several discontinuities appear in the curves connecting hardness and resistance with composition. At the exact compositions Cu_3Au and CuAu sharp minima occur on them. On each side of these compositions the resistance rises rapidly, while the hardness rises rapidly on each side of the composition CuAu. In an alloy containing 75 atomic per cent. of copper the Brinell hardness is 60 when quenched and 42 when slowly cooled, and in one containing 50 atomic per cent. of copper it is 115 when quenched and 100 when slowly cooled. In alloys containing 45 and 55 atomic per cent. of copper, respectively, the hardness is about 95 when quenched and 188 when slowly cooled. These alloys may therefore be obtained in a soft condition by quenching and may be hardened by reheating at a suitable temperature.

Similar changes occur in iron-aluminium alloys. Up to 33 per cent. of aluminium these consist of primary solid solutions in body-centred α-iron. As far as 9.9 per cent. the two kinds of atoms are distributed at random among the lattice points of the body-centred lattice. Then, as shown by Bradley and Jay, a symmetrical arrangement begins to form in slowly-cooled alloys. At 13.9 per cent. (25 atomic per cent.) all the aluminium atoms are situated on one of the four face-centred cubic lattices of which the body-centred cubic lattice may be said to be composed. This gives the superlattice Fe_3Al. Above this the atoms of aluminium begin to fill the lattice points on another of the four interpenetrating face-centred lattices. At 32.6 per cent. (50 atomic per cent.) this process is completed, and the superlattice FeAl results. The changes from the disordered to the ordered distribution of atoms in alloys containing between 10 and 33 per cent. of aluminium are influenced by the rate of cooling, and the effect of this on the physical properties has been studied by Sykes and Morgan. With the exception of electrical resistivity, the effects observed were small, and it therefore appears that the formation of FeAl or Fe_3Al is not accompanied by hardness changes like those caused by the formation of Cu_3Au and CuAu.

Changes of solid solubility are utilised to produce alloys of considerable practical importance. These occur in the systems of types (1) and (3), and their importance depends on the fact that they are influenced by the rate of cooling. In certain alloy steels of hypereutectoid composition, quenching from a high temperature is utilised to retain in solution as much carbide as possible, *e.g.*, in high-speed and austenitic manganese steels.

The changes of solid solubility of copper and Mg_2Si in aluminium are utilised in the heat-treatment of light aluminium alloys. At the eutectic temperature (548 deg. C.) aluminium dissolves 5.65 per cent. of copper. The solubility decreases rapidly as the temperature falls and is only 0.5 per cent. at 200 deg. C. By quenching, the formation of $CuAl_2$ may be prevented, and thus, depending on the quenching temperature, alloys containing up to 5.5 per cent. of copper may be retained at atmospheric temperatures as solid solutions. The same applies to those containing Mg_2Si. After quenching, pure aluminium-copper alloys and alloys of aluminium with copper and Mg_2Si undergo a change at atmospheric temperatures which results in an increase of strength and hardness. This is known as age-hardening. On heating, this proceeds more rapidly and is known as accelerated age-hardening. If, however, the time of heating is sufficiently prolonged or the temperature sufficiently high, the hardness reaches a maximum and then begins to decrease. In general, therefore, the change under consideration may be said to be accompanied first by an increase and then by a decrease in hardness.

In explanation of these changes, Merica, Waltenberg and Scott advanced the "critical dispersion" hypothesis, which attributed the increase in hardness to the precipitation of $CuAl_2$ or Mg_2Si in the form of submicroscopic particles, and the subsequent softening to their coalescence. This hypothesis was widely, but not universally, accepted, and more recent work has shown that the change is more complicated than was originally supposed. As a result of this hypothesis the terms precipitation and dispersion hardening came into use, and temper hardening is also employed in the case of alloys like copper-beryllium, copper - aluminium - silicon, copper-aluminium-nickel, iron-molybdenum, iron-tungsten, etc., which require to be heated to promote the changes in question.

The nature of the change that occurs when an unstable solid solution decomposes at atmospheric temperatures or during heating is by no means easy to discover. The most reliable criterion of the condition of the alloy is the lattice parameter of the solid solution. So long as this remains expanded or contracted by the presence of the solute atoms it is a solid solution. When it returns to the dimensions characteristic of the pure solvent metal precipitation has occurred. Intermediate stages involving a concentration of the dissolved constituent before precipitation should be marked by changes in the appearance of the lines on the X-ray spectrogram. In the aluminium alloys that harden at atmospheric temperatures the increase in hardness is not accompanied by a change in lattice parameter. Thus hardening may take place without precipitation. When the hardening is accelerated by heating it is accompanied by precipitation. But it remains to be seen whether it is due to this precipitation. It is not impossible that, under conditions which permit a certain amount of precipitation, the increase in hardness is caused by some change in the arrangement of the atoms still in solid solution.

The changes that remain to be considered are those that involve the formation of one phase from another, *e.g.*, ferrite from austenite, α from β brass, or the decomposition of a solid solution into two other constituents, *e.g.*, the eutectoid changes in steel, copper-aluminium alloys, etc. The transformation from austenite to ferrite and pearlite is the most important of all changes in solid alloys. The heat-treatment of steel is based on it, and many of the properties of alloy steels are due to the effect of the alloying elements on the course of this change. It has been the subject of innumerable investigations and yet important discoveries are still being made, as exemplified by recent work on the effect of austenite grain-size on the harden-ability and the mechanical properties of a steel of a given composition.

The eutectoid change in certain copper-aluminium alloys is of less practical importance, but it is, nevertheless, of great interest because of its similarity to the change in steel. When a steel of eutectoid composition is quenched the formation of pearlite is suppressed, but the austenite is not retained unchanged at atmospheric temperatures. During rapid cooling the space lattice of the iron changes from the face-centred to the body-centred form with the carbon held in solid solution. Owing to the presence of the carbon the space lattice of martensite is different from that of ferrite, and the unit cell is tetragonal instead of cubic, but the difference is one of degree and not of kind, for it increases progressively with carbon content. Similar results are obtained with copper-aluminium alloys. When an alloy of eutectoid composition is quenched from the β range the eutectoid transformation is suppressed, but β is not retained unchanged at atmospheric temperature. During rapid cooling the lattice changes from body-centred β to face-centred α, but owing to the retention in solid solution of more aluminium than is normally soluble the α lattice is distorted.

The structural aspects of the formation of the eutectoid in steel and aluminium bronze are very similar, and so are the results of accelerated cooling. But the effect of rapid cooling on the mechanical properties is quite different, for whereas steel of such composition is hardened by quenching and softened by tempering, aluminium bronze is softened by quenching and hardened by tempering.

To sum up, composition is the first factor to be considered in connection with the properties of an alloy. All properties depend on this to a greater or less extent, but other factors—constitution, structure and condition—are also important. The composition is fixed when the alloy is cast, while the other factors are influenced by the casting technique, and the heat and mechanical treatment of the solid metal. Most of the alloys used in the cast condition contain a eutectic, *e.g.*, the cast irons, aluminium-coppers, and aluminium-silicons. Bronze contains a eutectoid, while brass consists of solid solutions. Most of the alloys used in the worked condition solidify as solid solutions, *e.g.*, steel, brass, copper-nickel, and the heat-treatable alloys of aluminium. Finally, most of the alloys subjected to heat-treatment solidify as solid sclutions and undergo subsequent changes in the solid, *e.g.*, steel and the heat-treatable light alloys.

Heat-treatment consists of controlled heating and cooling operations designed to modify the properties of an alloy by promoting or preventing constitutional and structural changes. But these are also influenced by the presence of elements other than those required, which have to be reckoned with. Steel is the outstanding example of an alloy in which the mechanical properties depend on constitution and structure, and the control of these by heating and cooling and by the addition of other elements. The heat-treatable alloys of aluminium fall into the same category as do the more-recently developed heat-treatable alloys of copper and nickel. Certain elements facilitate the retention of the soft condition by quenching, others promote the necessary precipitation hardening during the cooling of a chill casting or a hot stamping, others accelerate or retard precipitation hardening at atmospheric or elevated temperatures, while others may be used to raise the recrystallisation temperature so that the hardening due to cold-working and precipitation may be simultaneously utilised.

Sir Robert Hadfield (Past-President) said the very pleasant duty had fallen to him of proposing a vote of thanks to the President. The President had given a most admirable address on the pure science side of metallurgy, and the members were greatly indebted to him. When one thought of the importance of alloys, especially of iron, to-day, one would realise all that that implied. The President had put before the Institute a very admirable study of alloys from the pure scientific side, and the members were greatly indebted to him for his address.

The vote of thanks was carried unanimously, with acclamation.

The President thanked Sir Robert Hadfield very much for the kind words he had used in moving the vote of thanks. It was a great pleasure to him that the vote of thanks should

(*Concluded on page* 316.)

The Welding of Cast Iron: Some Metallurgical Considerations*

By J. G. PEARCE, M.Sc., F.Inst.P., M.I.E.E. (British Cast Iron Research Association)

While welding is used to a small extent for the fabrication of cast parts in the ordinary course of manufacture, in the main its greatest application to cast iron lies in repair work. Some metallurgical considerations bearing upon welding are advanced in the conviction that the production of a sound weld is essentially a metallurgical operation, and the extent to which a weld is successful is governed by the extent to which it conforms with metallurgical requirements. The metal deposited during the welding operation is essentially a casting, hence founders and welders are mutually interested in advances in the art and science of casting. While a large amount of work has been done in developing the welding process, the welding of cast irons still awaits full scientific investigation and application of existing knowledge.

Metallurgical Considerations

Unless the parent metal is preheated, the rate of cooling is so rapid as to amount to chilling or quenching from a high temperature. In spite of the high temperature reached during the operation, the actual amount of heat communicated to the parent metal during welding is comparatively small, and this is rapidly conducted away on account of the relatively high thermal conductivity. Under these conditions the structures which normally form in cast iron under slow cooling do not have time to form and the structure is chilled. The aim of the founder to-day in manufacturing ordinary castings is to adjust the composition and rate of cooling so as to yield in the cold an all-pearlitic iron, the structure being interrupted only by phosphide eutectic (in the phosphoric irons), free graphite, and occasional crystals of manganese sulphide. In an all-pearlitic iron the combined carbon is 0.8 to 0.9 per cent., the remainder of the total carbon being present as graphite. An average iron containing 2 per cent. silicon and 1 per cent. phosphorus has a total carbon content, in the eutectic condition, of 3.4 per cent. Such an iron melts at about 1,100 deg. C. In recent years the very marked improvement in the mechanical properties of grey iron has been obtained by reducing the amount of total carbon, which increases the proportion of combined carbon and reduces the graphite both in size and in quantity. When metallurgical control was less general than is now the case, founders tended to offset the risk of hard spots and unmachinability (due to free cementite) by using a higher silicon content. As this element is a powerful graphitiser, the final structure in the cold was a mixture of ferrite and pearlite, due to the graphitisation of the carbide laminations in some of the pearlite areas and their conversion to ferrite and graphite. An iron completely or partially pearlitic can be made completely ferritic by an annealing process. Simple low-temperature annealing, not exceeding 400 deg. C., can be arranged to relieve casting stresses without appreciable effect on the structure. Annealing for a longer time at a higher temperature can be arranged to effect the change from pearlite to ferrite so as to yield an iron of maximum softness and machinability, with some reduction in mechanical properties. By a still more drastic annealing, irons containing free cementite can be converted to the pearlitic or ferritic condition. Preheating has an annealing influence, depending on the time and temperature reached, and this influence is important in view of the argument below as to whether carbide or graphite is the source of blowholes and gaseous inclusions during welding.

It is impracticable at present to produce cast iron wholly ferritic in the cast state without annealing. While an approximation can be obtained by using a high-silicon content, this course is undesirable, since, although silicon is a powerful graphitising agent, it also embrittles the matrix of the metal, in which it dissolves, and materially raises the Brinell hardness. This effect of silicon places a limit to its use.

Carbon Content

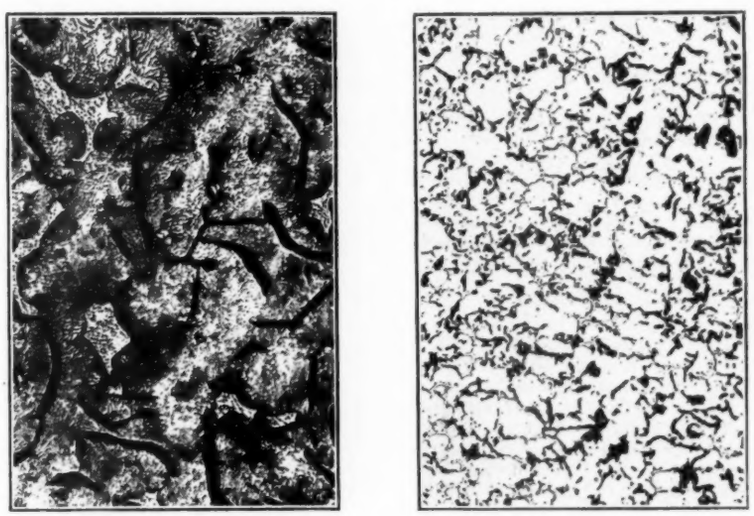
The properties of cast iron which affect the success or failure of welds—strength, ductility, thermal expansion and contraction, thermal conductivity, temperatures of pearlite change and melting—depend in the main on the carbon content. The effect of other elements is either direct or indirect through their influence on the carbon and its relationship to the iron. The thermal conductivity of an ordinary grey iron with about 2 per cent. silicon and 1 per cent. phosphorus is approximately 0.110 unit (cal. per sq. cm. per sec. for 1 deg. C. difference in temperature per cm.) at air temperature, falling to 0.100 unit at about 500 deg. C.[1] As the conductivity of ferrite is materially greater than that of pearlite, which in its turn is greater than that of cementite, the conductivity falls as the iron passes from the ferritic to the pearlitic or cementitic condition, and conductivity depends on structure as well as composition. The figure given is for a mainly pearlitic iron. The coefficient of thermal expansion of cast iron is about 1.4×10^{-5} and does not differ materially with composition or as between ferritic and pearlitic irons.[2] For mottled and white irons there is a slight change at about 250 deg. C. Below 250 deg. C. the expansion falls short of the figure given and above this temperature exceeds it.

All ferrous materials subjected to elevated temperatures in the presence of air tend to oxidise or scale. Cast irons are also subject to another phenomenon, that of growth; it is equivalent to the external process of scaling, but takes place internally. Oxidising gases penetrate the metal along cavities partially filled with graphite and oxidise the metal in the immediate neighbourhood of the flake. This oxidation involves an irreversible increase in volume which, on account of the restriction to free expansion, sets up a state of stress which sooner or later relieves itself by the formation of a minute crack. These cracks offer further opportunities to gaseous penetration, and extend, and the process proceeds cumulatively. Under laboratory conditions it is practicable to make irons grow far beyond the limits of their utility in service. Various irons have been produced in recent years to meet the demands of heat-resisting service, being resistant to both growth and scaling,[3,4] and in the best of these growth has been reduced to figures materially less than ordinary thermal expansion at the temperatures involved. These irons are austenitic in the cold state and are referred to in what follows.

Contraction and Expansion

When ordinary cast iron is heated in a welding operation, the metal expands normally up to a temperature of about 600 deg. C. when the expansion begins to increase at a greater rate than the temperature. A point is reached at about 760 deg. C. when a marked constitutional change takes place. The fire graphite begins to dissolve and the metal becomes austenitic instead of pearlitic. This change is accompanied by a definite contraction in volume. When the solution of graphite is complete, expansion continues. The pearlite change-point on cooling is usually at a temperature slightly higher than on heating. Corresponding with the contraction on heating when graphite is dissolved, there is an expansion on cooling when graphite is redeposited and the expansion is generally greater than the contraction. This results in the metal, after heating, being slightly larger in volume than before heating, and the difference is the growth for that particular cycle. The solution of graphite at the pearlite point is the reason why malleable cast iron cannot be welded in the ordinary way, as the influence of the annealing operation is destroyed. The cooling is too rapid to prevent the formation of cementite. Joints can be made, however, with an alloy such as brass or bronze, since it is not then necessary to reach the pearlite point during the operation, but the joint can scarcely be regarded as a true weld.

The first stage of heat deterioration is the change from pearlite to ferrite, which Benedicks



(*a*) Ordinary Cast-Iron Parent Metal. (*b*) Weld Metal.

FIG. 1.—AFTER OXY-ACETYLENE-WELDING THE BAR WITH SIMILAR METAL. × 200.

* Paper contributed to the Symposium on the Welding of Iron and Steel.

has calculated[5] involves a volume increase of 2 per cent. in the case of an all-pearlitic iron. This change can proceed in the absence of air. The second and more serious change is that of oxidation of ferrite, and the total volume increase yielded by these changes constitutes growth. The presence of phosphorus in an iron leads to the formation of considerable quantities of phosphide eutectic, and this constituent melts at 960 deg. C., well below the melting point of the iron, and hence below the temperature of the welding process. It is found from experience, however, that this hard brittle eutectic, which does not change its character under heat (except that a terniary eutectic containing carbon may become a binary) remains comparatively rigid up to its melting temperature. The inclusion of phosphorus (up to as much as 1 per cent.) has been noted in welding rod, and its presence will undoubtedly facilitate the melting of the rod and promote its fluidity. At the same time, the mechanical properties of the phosphide eutectic render the inclusion of phosphorus of doubtful value.

The use of welding rod high in silicon, partly to offset the loss of silicon by oxidation during the welding process and partly to ensure a soft deposit, is of interest, as silicon has a remarkable effect in raising the pearlite change-point. It is, however, impracticable to raise it above the temperature of the welding process, and on other grounds previously mentioned, the use of excessive silicon is undesirable. If the state of affairs during the heating up of the metal for welding be visualised, it will be realised that there is a marked thermal gradient from the weld deposit into the body of the casting. The heated part is raised to a high temperature, and thus a stress is set up on account of the restraint exercised by the cooler metal at the back. This condition is aggravated by the changes at the pearlite point, and a condition arises in which metal at the working face passing through this point is actually contracting, while metal immediately behind it a little lower in the thermal gradient is expanding.

Advantage of Preheating

The internal stress set up during welding without preheating is likely to arise not at the weld itself, but at a point outside the weld, at the junction between the heated and unheated metal; this weakness is responsible for some cases of test-bars of welded parts failing outside the weld. Preheating has the great advantage of minimising these stresses and allowing the casting, including the weld metal, to cool more naturally. Still greater, however, is its advantage in preventing the weld deposit from chilling, with the result that under preheated conditions the weld deposit much more resembles the metal in the body of the casting. Preheating is, therefore, a very great advantage; indeed, welding in the cold is best done with a Monel-metal rod, which, by virtue of its intrinsic ductility, has the power to take up, without cracking, any stress arising from the operation.

The Cast Iron Research Association has from time to time shown that it is possible to obtain cast-iron structures of widely varying character, although the chemical composition remains practically the same.[6 7] In this connection, it must be emphasised that compositions of cast irons are similar if their contents of total carbon, silicon, manganese, sulphur and phosphorus are similar. Irons which differ only in combined carbon content—that is, in the way the total carbon is divided between combined carbon and graphite—cannot be regarded as differing chemically. The division of total carbon into these two components is determined entirely by the conditions of melting and cooling. It has been shown that irons of a given composition may exist either in the usual pearlite/flake-graphite condition or in another condition which is structurally ferrite/fine-graphite. This second condition in the laboratory can be obtained in various ways by various devices, such as superheating or by the incorporation of steel with the charge. It is frequently observed, however, that the ferrite/fine-graphite condition is obtained in ordinary practice, when the cooling is exceptionally rapid, as, for example, in many light castings. The structure in such cases is not in this condition throughout, but is a mixture of

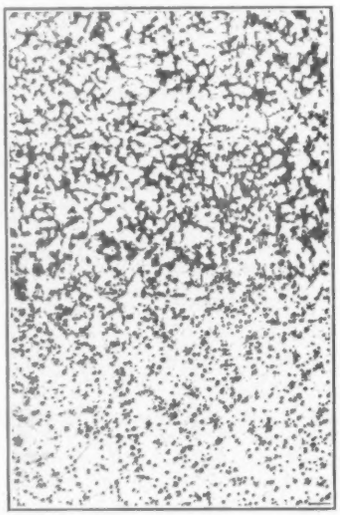


Fig. 2.—Joint of Electrical Weld of Austenitic Cast Iron with Monel Metal. × 50.

colonies of ferrite/fine-graphite with pearlite/flake-graphite, which frequently includes the whole of the phosphide eutectic, increasing in those areas the structural concentration of phosphorus. The fine-graphite/ferrite structure has been observed in weld metal. These two types of structure have differing physical and mechanical properties, such as strength, ductility, hardness, thermal conductivity, thermal expansion.

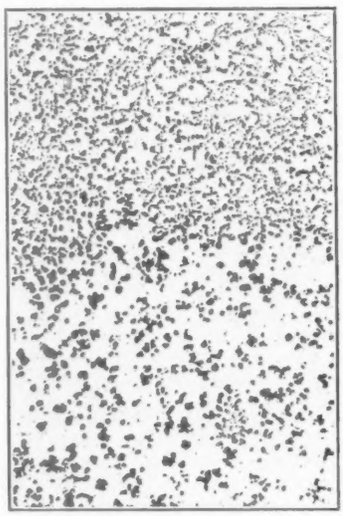


Fig. 3.—Joint of Oxy-Acetylene Weld of Austenitic Cast Iron with Similar Material. × 50.

In the early days of cast-iron welding it was found that, without preheating, the weld deposit was chilled white, partly due to the rapid cooling and partly due to the loss of silicon and manganese by oxidation during the process. The adoption of preheating and the use of high-silicon rod has not, however, yielded a deposit structurally similar to the parent metal, however it may resemble it chemically, the reason being that the conditions of melting and cooling in the two cases are so widely different. Fig. 1 (*a*) shows the parent metal and Fig. 1 (*b*) the weld metal of an ordinary cast-iron bar, oxy-acetylene welded with similar metal. The original metal is pearlitic with coarse graphite and the weld metal ferritic with finer graphite. Provided a good weld is obtained, however, there is no reason why the weld deposit metal should not be superior in its properties and structure to that of the parent metal. The author has never seen metal weld similar in structure to the parent metal in cast-iron welds.[8] The autogenous welding of cast iron has been practised in foundries for many years in the process known as burning-on, in which a casting is repaired by new metal cast into the required spot, molten metal being run through until the area to be repaired is either molten or pasty. The structure of a burnt-on joint is similar in many ways to that of a welded joint.

Effect of Graphite

It is usually considered that difficulties arise in the welding of steel containing more than 0.3 per cent. carbon. Practical experience has shown that greater difficulties are experienced in welding cast iron than in welding steel, and the cause is frequently attributed to the presence of graphite, which the practical man regards as the main difference between the two materials. Gaseous inclusions are attributed to the oxidation of the graphite. This view is not strictly correct. For example, in the finely-graphitic, heat-resisting irons developed by the Cast Iron Research Association, known as Silal, the graphite is in an extremely fine state of division. If flake graphite were readily oxidised, fine graphite would be still more so, but actually the Silal irons are extremely heat- and scale-resisting, and other things being equal, the finer the graphite structures the greater is the resistance. In white-heart malleable-annealing practice, castings made in white, graphite-free iron, are softened by heating in a highly-oxidising atmosphere at a comparatively high temperature. It is generally accepted that the carbide or cementite in a white iron is oxidised while graphite is deposited as a consequence of the operation. The question has recently been examined quite independently and from a different point of view by G. L. Bailey[9] for the Non-Ferrous Metals Research Association. In examining certain defects in non-ferrous ingots, due to the evolution of gas from the surface of cast-iron moulds, loss of graphite by oxidation naturally suggested itself as a possible cause of gas evolution. However, tests showed that the amount and state of division of the graphite did not influence the gas evolution. It was then thought that the gas was formed by a reaction between the carbide present in the mould in the pearlite and a superficial oxide film, and further research confirmed the supposition that decarburisation proceeds at the expense of combined carbon and not of graphite.

While graphite, however, is comparatively stable compared with cementite, there is no doubt that it will oxidise at elevated temperatures in the presence of oxygen, and irons subjected to heat have been examined showing that, although the metal in the neighbourhood of a graphite flake is oxidised more rapidly than the flake itself, ultimately the graphite disappears as oxides of carbon. A. L. Norbury has also shown, in the laboratories of the Cast Iron Research Association, that gas evolution may arise to a limited extent from the oxidation of graphite. Hence, while graphite may be responsible for some of the difficulty of welding cast iron, it is more likely to be due to the combined carbon, the oxidation of which causes blowholes and gaseous inclusions. A ferritic iron should be more easily welded than a pearlitic iron, and preheating or preliminary annealing, by converting pearlite to ferrite, should facilitate welding, quite apart

(*Concluded on page* 316.)

The Institute of British Foundrymen

ANNUAL CONFERENCE AT SHEFFIELD

As previously announced, the thirty-second annual conference of the Institute will be held in Sheffield from July 2 to 5. In view of the unique part played by the Sheffield district in the development of the iron and steel industries, every effort has been made to render the occasion a memorable one, both to Sheffield and to all those attending the conference. Papers of a high technical standard will be discussed, and visits to important works in the Sheffield district have been arranged. During the conference the headquarters of the Institute will, by the kind invitation of the University of Sheffield, be located in the Applied Science Department of the University, St. George's Square, Sheffield. The foundry department, established in connection with the new degree foundry course, is now well equipped, and members will have an opportunity of examining it.

In view of the fact that last-minute applications greatly increase the work of organising a conference of this nature, members are particularly urged to complete and forward their reply form as early as possible. It would greatly assist the organisers if, during the conference, members would be punctual at all timed functions, since unpunctuality may cause serious dislocation of the programme arranged. For members coming to Sheffield by rail, "summer" tickets available for a month may be obtained from practically all stations, at about one and a-third fares for the double journey, so that no special vouchers are required.

Programme

Tuesday, July 2.

5.0 p.m.—Annual general meeting in the Mappin Hall, St. George's Square, open to all members, associate members and associates.

7.30—8.0 p.m.—Reception in the Town Hall, Sheffield, by the kind invitation of the Lord Mayor of Sheffield (Alderman P. J. M. Turner) and the Lady Mayoress. (All members and ladies.) Buffet supper and dancing. (Evening dress.)

Wednesday, July 3.

9.15 a.m.—Conference opens at the University of Sheffield. (All members and ladies.) Welcome in the Mappin Hall, St. George's Square, by the Vice-Councillor of the University of Sheffield (Dr. A. W. Pickard-Cambridge); the Lord Mayor of Sheffield (Alderman P. J. M. Turner, J.P.); the Lord Bishop of Sheffield; the Master Cutler (Mr. A. Williamson); the Provost of Sheffield (Rev. Dr. A. C. E. Jarvis) and the President of the Sheffield Chamber of Commerce (Mr. A. K. Wilson). Presentation of the Oliver Stubbs Medal; presidential address by Mr. J. E. Hurst.

10.45 a.m.—The first Edward William Lecture, by Sir William Larke, K.B.E. (honorary member). Subject: "Man and Metal." (This Paper will not be printed in advance of the conference.)

11.45 a.m.—Discussion of Papers Nos. 562 and 563 in the Mappin Hall. *Note.*—At this conference all Papers will be taken as read, to afford adequate time for the discussion of each.

12.30 p.m.—Conference adjourns.

1.0 p.m.—Luncheon at the Grand Hotel, by invitation of the Sheffield Branch. (All members and ladies.)

2.30 p.m.—Omnibuses leave the City Hall for the following works visits:—(1) Steel, Peech & Tozer, Limited, The Ickles, near Sheffield (large modern open-hearth steelmaking plant and high-capacity rolling mills); (2) Hadfields, Limited, Tinsley, Sheffield (large steel foundries and engineering shops); (3) Sheepbridge-Stokes Centrifugal Castings Company, Limited, Sheepbridge (centrifugally-cast cylinders, liners, etc., in ordinary and alloy irons); (4) Foundry Department of the University of Sheffield (melting, moulding and other equipment used in Foundry Degree Course). *Note*: Each visit will occupy the whole afternoon, so that members may attend one only.

7.0 p.m.—Reception by the President and Mrs. J. E. Hurst prior to the annual banquet.

7.30 p.m.—Annual banquet at the Royal Victoria Station Hotel, with entertainment and dancing. (Evening dress. A dressing room will be provided at the Royal Victoria Hotel from 6.30 p.m.)

Thursday, July 4.

9.30 a.m.—Conference continues at University of Sheffield; Session A in the Mappin Hall. Symposium on steel castings and kindred subjects. Discussion of Papers Nos. 564, 565, 566, and 567. Session B in Room B1; discussion of Papers Nos. 568, 569, 570 and 571.

12.30. p.m.—Conference adjourns.

1.0 p.m.—Luncheon at the Grand Hotel (members and ladies).

2.30. p.m.—Omnibuses leave the City Hall for the following works visits:—(1) English Steel Corporation, Limited, Grimesthorpe and Vickers Works, Sheffield (steel foundry, new open-hearth and heavy-forge departments, and heavy-machine shops); (2) Newton Chambers & Company, Limited, Thorncliffe Works, Chapeltown (blast furnaces, jobbing and specialised iron foundries); (3) General Refractories, Limited, Worksop (modern refractories plant, manufacture of bricks for all purposes); (4) United Steel Companies' research laboratories, and high-frequency induction furnaces of Samuel Fox & Company, Limited, Stocksbridge (up-to-date research department and modern melting unit of large induction furnaces for manufacture of special steels). *Note*: Each visit will occupy the whole afternoon, so that members may attend one only.

7.30-8.0 p.m.—Reception (members and ladies) by kind invitation of the Vice-Chancellor of the University and Mrs. A. W. Pickard-Cambridge in the Firth Hall, Western Bank, followed by dancing (evening dress).

Friday, July 5.

Excursion for Members and Ladies.

11.30 a.m.—Drive into Derbyshire by motor coach.

1.30 p.m.—Lunch at the Marquis of Granby Hotel, Bamford.

2.30 p.m.—Short drive by motor coach.

3.30 p.m.—Arrive at the Rising Sun Hotel, Hope. Garden party by the kind invitation of the President and Mrs. J. E. Hurst.

6.30 p.m. (approx.).—Return to Sheffield by motor coach.

Ladies' Programme

Tuesday, July 2.

7.30—8.0 p.m.—Reception in the Town Hall (see general programme).

Wednesday, July 3.

9.15 a.m.—Ladies are invited to attend the opening of the conference in the Mappin Hall, St. George's Square (see general programme).

1.0 p.m.—Luncheon at the Grand Hotel, by invitation of the Sheffield Branch.

2.30 p.m.—Visits to the following:—(1) Arthur Davy & Sons, Limited (modern food factory); (2) Walker & Hall, Limited (manufacture of cutlery, electroplate, silver goods); (3) City Hall and Central Library. *Note.*—As each visit will occupy the whole afternoon, ladies may attend one only.

7.0 p.m.—Reception by the President and Mrs. J. E. Hurst at the Royal Victoria Hotel.

7.30 p.m.—Annual banquet (see general programme).

Thursday, July 4.

1.0 p.m.—Luncheon at the Grand Hotel.

2.30 p.m.—Visits to the following:—(1) Painted Fabrics, Limited (fancy goods made by disabled soldiers and sailors); (2) Wm. Gunstone & Sons, Limited (manufacture of biscuits); (3) "Sheffield Telegraph" (modern printing works). *Note.*—As each visit will occupy the whole afternoon, ladies may attend one only.

7.30—8.0 p.m.—Reception (see general programme).

Friday, July 5.

11.30 a.m.—Whole-day excursion, lunch and garden party (see general programme).

Programme of Papers

Wednesday, July 3.

First Edward Williams' Lecture, "Man and Metal," by Sir Wm. J. Larke, K.B.E. (honorary member).

No. 562, "Refractories for Foundry Use," by W. J. Rees, M.Sc. (member), head of Refractories Department, University of Sheffield.

No. 563, "Sand Problems in a Brass Foundry," by F. Howitt, Peglers, Limited, Doncaster.

Thursday, July 4.

SESSION A.—SYMPOSIUM ON STEEL FOUNDRY PRACTICE.

No. 564, "Steel Castings," by W. H. Hatfield, D.Met. (member), Director, Thos. Firth & John Brown, Limited.

No. 565, "Research on Steel Castings," by Prof. J. H. Andrew, D.Sc. (member), Dean of the Faculty of Metallurgy, University of Sheffield.

No. 566, American Exchange Paper, "A Note on the Influence of Temperature Gradients in the Production of Steel Castings," by George A. Batty (presented on behalf of the American Foundrymen's Association).

No. 567, "Castings," by W. Machin (member) and M. C. Oldham, Vickers Armstrongs, Limited, Barrow-in-Furness.

SESSION B.

No. 568, "Some Notes on Ingot Moulds," by T. Swinden, D.Met. (member), and G. R. Bolsover, F.Inst.P., Central Research Department, United Steel Companies, Limited.

No. 569, French Exchange Paper, "The Making of Large Castings by Loam Moulding," by Henri Fabre, Société des Etablissements Bracq-Laurent (presented on behalf of the Association Technique de Fonderie).

No. 570, German Exchange Paper, "German Ironfoundry Progress in Piston Rings, Brake Drums and other Automobile Castings," by William A. Geisler (member), Alfred Teves, Masch. & Armaturen Fabr. G.m.b.H., Frankfurt, Germany (presented on behalf of the Verein Deutscher Eisengiessereien Giessereiverband).

No. 571, "Relationship in Cast-Iron Test Results," by G. L. Harbach (associate member), Worthington Simpson, Limited, Newark.

Hotel Accommodation

It will be very difficult to obtain hotel accommodation in Sheffield in July next unless early application is made, owing to the fact that other functions are taking place at the same time as the conference. Members are therefore urged to reserve their hotel accommodation as far in advance as possible.

General Notes

Registration.—Members and ladies attending the conference will receive per post prior to reaching Sheffield a registration card bearing the member's registration number. This card should be exchanged upon arrival at the conference office for a booklet of tickets for the functions and visits indicated on the member's reply form. Members who desire to have their tickets, Papers, etc., forwarded to them in advance of the confer-

ence, may obtain them by enclosing an additional 4d. per head when sending their remittances to the general secretary.

Conference Office and Information Bureau.—The office will be open for the issue of tickets, booklets, copies of Papers, etc., as follows:—Room B4, Applied Science Department, St. George's Square, Sheffield: Tuesday, July 2, 2 p.m. to 6 p.m.; Wednesday, July 3, 9 a.m. to 12 noon; Thursday, July 4, 9 a.m. to 12 noon.

Souvenir Booklet.—A souvenir booklet giving full details of the programme, notes of the district, works to be visited, etc., will be supplied to each member and lady attending the conference.

Badges.—In view of the issue of membership badges to all members of the Institute, it has been decided not to issue a separate conference badge. A special badge will be provided for the ladies. The Institute's badge is engraved with the member's name and year of election. Any member who is not already in possession of a badge may obtain one at a charge of 2s. by applying to the general secretary before June 8.

Correspondence.—Members may have their correspondence forwarded to them during the conference period, addressed:—C/o The Institute of British Foundrymen, Applied Science Department, St. George's Square, Sheffield, 1. Letters so addressed will be available at the conference office, room B4.

Guarantee Fund for the 32nd Annual Conference

In connection with the conference a Guarantee Fund has been opened. The honorary convention secretary, Mr. T. R. Walker, B.A., The Priory, Oughtibridge, near Sheffield, will be pleased to have further sums guaranteed.

Firm.	Amount guaranteed. £	s.	d.
English Steel Corporation, Limited ...	30	0	0
Thos. Firth & John Brown, Limited...	30	0	0
Hadfields, Limited	30	0	0
Brightside Foundry & Engineering Company, Limited	25	0	0
Hall & Pickles, Limited	20	0	0
Stanton Ironworks Company, Limited	20	0	0
Durhills, Limited	20	0	0
George Oxley & Sons, Limited ...	20	0	0
Kayser, Ellison & Company, Limited	15	0	0
Arthur Balfour & Company, Limited	15	0	0
Ford Motor Company, Limited ...	15	0	0
John Fowler (Don Foundry), Limited	15	0	0
Mond Nickel Company, Limited ...	15	0	0
High Speed Steel Alloys, Limited ...	15	0	0
Markham & Company, Limited ...	10	0	0
Harrison Bros. (England), Limited ...	10	0	0
F. Parramore & Sons, Limited ...	10	0	0
Pickford, Holland & Company, Limited (subscription in full) ...	10	10	0
Thos. Black, Limited	5	0	0
Joseph Boam, Limited	5	0	0

The Iron and Steel Institute

(*Concluded from page* 312.)

be moved by a man who had produced one of the most famous alloys that ever existed, manganese steel. He would like to add that he had been greatly assisted in the preparation of the address by a member of his own staff, Dr. J. M. Robertson, and he would like to make public acknowledgment of that fact.

Welding Symposium

In connection with the meeting of the Iron and Steel Institute, a symposium on the welding of iron and steel was held on Thursday, May 2, and continued next day. At the Science Museum, South Kensington, an exhibition of welding was opened on the previous evening, when a Conversazione was held and several films depicting welding operations exhibited. One of the Papers submitted at the symposium will be found elsewhere in this issue, and a selection from the others will be published later.

The Welding of Cast Iron: Some Metallurgical Considerations

(*Concluded from page* 314.)

from its effect in reducing stress due to expansion and contraction, and avoiding chilling of the weld deposit.

Influence of Manganese and Silicon

So far as the other elements ordinarily present are concerned, the harmful effects of manganese appear to have been exaggerated, and this element should be present in quantities normally required to neutralise the sulphur, which thus yields sulphur in its least harmful form as the neutral inclusion, manganese sulphide. The Cast Iron Research Association has shown that this should be the atomic proportion manganese/sulphur plus an excess of 0.3 per cent. The minimum manganese should therefore be 1.7 S per cent. plus 0.3 per cent. The embrittling effects of silicon have been mentioned, and in this connection nickel has a graphitising effect less powerful than silicon and may conveniently be used to replace part of the silicon. Nickel has the advantage of making the matrix tougher and more ductile rather than more brittle.

Austenitic irons are formed because certain elements added to cast iron lower the pearlite change-point, and in sufficient quantity will reduce it to below atmospheric temperature, so that the normal structure of the metal in the cold is austenitic. Their high resistance to oxidation makes them useful in welding processes, as they do not pass through the pearlite change-point or suffer its consequent structural disturbances on heating. The austenitic irons containing nickel, copper and chromium are highly heat-resisting and, further, are corrosion-resisting, soft and easily machinable, non-magnetic and have a slight measure of ductility in the cold state in addition to their greater resistance to growth and scaling.[4] The thermal conductivity is slightly less than that of a pearlitic iron (for example 0.07 unit, for Nicrosilal at air temperature falling to about 0.05 unit at about 400 deg. C.) and the thermal expansion is slightly higher (1.8×10^{-6}). Two of these irons are commercially established. Niresist contains 12 per cent. of nickel, 6 per cent. of copper, with varying proportions of chromium, and Nicrosilal contains 18 per cent. of nickel, 6 per cent. of silicon and 1-3 per cent. of chromium. Welders have found that these irons are greatly superior to ordinary cast irons in welding on account of their resistance to oxidation and should obviously be used for the welding of austenitic irons. The use of austenitic irons for welding pearlitic irons is attractive, but as the austenitic material becomes diluted with the pearlitic, there is the risk of the formation of martensite, a hard and unmachinable constituent.

Fig. 2 depicts the junction of an electric weld of an austenitic iron of the nickel-copper-silicon type (Nicrosilal) welded with Monel metal. Fig. 3 shows the junction of an oxy-acetylene weld between two pieces of the austenitic iron of the same type.

Conclusion

Experience of the examination of cast-iron welds suggests that the welding of cast iron can now be very satisfactorily accomplished. While it is impracticable to examine the composition and structure of every casting requiring to be welded, with a view to preparing a suitable welding rod, it should be quite possible to prepare rods suited to the repair of various grades of cast iron in ordinary use. Preheating is highly desirable as a preliminary to welding, not only to minimise the effects of stress but to facilitate the deposition of soft and machinable material reasonably similar to the parent metal. If this is done the silicon in the welding rod requires to be in excess of that in the metal only to the extent of the actual loss of silicon during welding. The possibilities of the austenitic irons of the nickel-chromium-copper type and of the nickel-chromium-silicon type require to be fully explored.

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6 A. L. Norbury: "Constitutional Diagrams for Cast Irons and Quenched Steels," "Journal of the Iron and Steel Institute," 1929, No. I, pages 443–471.

7 A. L. Norbury and E. Morgan: "The Effect of Melting Conditions on the Microstructure and Mechanical Strength of Grey Cast Irons containing Various Amounts of Carbon and Silicon," "Journal of the Iron and Steel Institute," 1930, No. I, pages 367–391.

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A.S.T.M. 38th Annual Meeting

In order to provide ample time for the presentation of the many technical reports and Papers which will be presented at the thirty-eighth annual meeting of the American Society for Testing Materials, to be held in the Book-Cadillac, Detroit, June 24-28, sixteen sessions are scheduled. During the five days of the annual meeting, the society's third exhibit of testing apparatus and related equipment will be in progress.

While Monday, June 24, will be devoted to meetings of many of the society committees, the annual meeting opens the next day with an address of outstanding interest by Mr. C. F. Hirshfeld, chief of research department, Detroit Edison Company, and the presentation of the President's address by Dr. von Schrenk, to be followed by the report of the executive committee and introduction of the new officers. The Tuesday afternoon meeting will comprise a session on testing, including Papers on elastic strength and its determination, hardness testing of light metals and alloys, relation between tension, static and dynamic tests and description of a new method for dynamic hardness testing. A session of unusually wide interest, held on Tuesday evening is to be devoted to a symposium on the place of materials in roads and motors.

The Edgar Marburg Lecture will be given on Wednesday afternoon. Dr. L. B. Tuckerman, of the National Bureau of Standards, will deliver the lecture on "Aircraft: Materials and Testing." The annual A.S.T.M. dinner is to be held on Wednesday evening, and will be followed by two addresses on "The Relationship of Materials to the House of To-day and To-morrow." The two sessions on Thursday morning are devoted to corrosion and its related problems and coal and coke, textiles and electrical insulating materials. Sessions on Thursday evening are devoted respectively to fatigue and effect of temperature on metals, covering tests on tin bronzes at elevated temperatures, creep characteristics of aluminium alloys, high-speed fatigue tests on metals, and a fatigue machine for testing small-diameter wire.

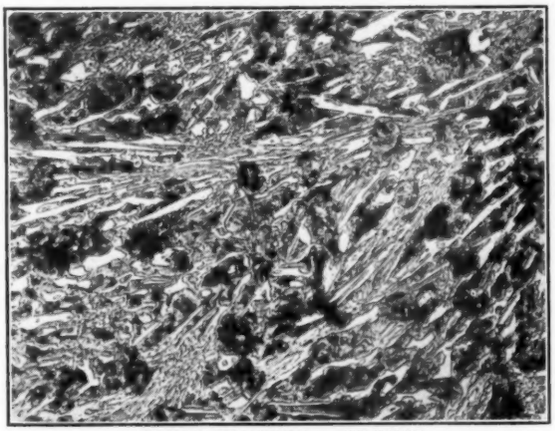
In addition to displays by leading companies in the testing instrument and related apparatus fields, the A.S.T.M. exhibit will include non-commercial apparatus sponsored by A.S.T.M. committees or research laboratories for the carrying out of special tests and research work. In this group of displays there will be a special high-speed fatigue testing machine, a low-capacity impact machine, a machine for making bending tests in wire used for mounting vacuum tube elements, apparatus used for special tests of electrical insulating materials and others.

XUM

Bradley's

REFINED CHROMIUM ALLOY PIG IRONS

One of the difficulties of ensuring regularity and uniformity of the chromium contents in chromium alloy cast iron arises from the high melting points of chromium and rich ferro-chromes. The melting point of pure chromium itself is high, viz., 1620°C. The ferro-chromium alloys are likewise refractory, and in the high chromium, ferro-chromes containing 6 to 8% carbon, there exist compounds which only melt completely above temperatures of 1600 to 1700°C. These temperatures are considerably higher than the freezing point of the eutectic iron carbon alloy which is 1150°C.



ETCHED STRUCTURE. × 200 DIAMS.

PHOTOMICROGRAPHS SHEWING STRUCTURE OF BRADLEY'S 8% CHROMIUM BRAND CF. REFINED CHROMIUM ALLOY PIG IRON

CHEMICAL COMPOSITION.

Total Carbon ...	2·95%	Sulphur ...	0·081%
Silicon... ...	3·05%	Phosphorus ...	0·061%
Manganese ...	0·81%	Chromium ...	8·06%

Bradley's 8% Chromium Brand CF Refined Alloy Pig Iron is designed to have a melting point as nearly as possible identical with that of ordinary cast iron, viz., 1150°C. The composition is based upon the approximate composition of the ternary iron-carbon-chromium eutectic, which is given as 8% Chromium, 3·6% Carbon (VON-VEGESACK). In Practice Brand CF can be supplied with the contents of Total Carbon, Silicon, Sulphur, Phosphorus and Manganese to suit requirements of individual customers.

In addition to Brand CF we make and supply Refined Chromium Alloy Cast Iron containing all percentages of Chromium up to 25%.

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Alloy Cast Irons*

BY A. T. WEARE.

The production of alloy cast irons has received considerable attention during recent years. Investigations have generally been confined to the influence of small additions of special elements, and results have shown how valuable these small additions are in improving the physical properties of cast iron. Much of the work has been carried on in the laboratory, but for a number of reasons its applications on a practical scale have not made the degree of progress conditions warrant.

Improvement in the properties of cast iron increases its competitive value, and enables it to be used with greater confidence for high-duty service. The high cost of production and difficulties encountered in melting and casting have been retarding influences in the greater development of alloy cast irons, but these difficulties are being overcome, and with the increasing need for materials that give adequate service, under exacting conditions, the cost factor should be given a broader interpretation. At the same time, there is a potential danger to what is a hopeful metallurgical development of considerable practical assistance to the foundryman and the engineer. The danger seems to lie in the tendency to claim too much, and to expect too much from these alloy additions to cast iron.

Effect of Nickel

With additions of nickel to grey cast iron varying between 1 and 2 per cent., the iron is still grey throughout, and it can be machined without difficulty. The combined carbon is in a fine pearlitic state, and the graphite is split up in the dendritic form. As the nickel content is increased, the pearlitic structure of combined carbon becomes sorbitic, and with a further increase to a content of between 5 and 7 per cent., the structure becomes definitely martensitic, in which the condition is hard and difficult to machine. An increase of nickel above 7 per cent. causes the structure to change gradually, until with over 20 per cent. the iron becomes completely austenitic, with properties quite different from ordinary cast iron. It is perhaps necessary to emphasise that nickel additions give the best results when added to a base iron of good composition and structure. The composition of the iron, apart from silicon and special alloy additions, depends upon the particular application; generally speaking, however, alloy cast irons are usually only for high-quality applications, and a good grade of base iron should be employed. Phosphorus and sulphur should be kept low—below 0.5 and 0.12 per cent. respectively—while carbon should be controlled with the silicon, and manganese generally kept on the high side.

The available methods of adding the alloying elements to the base iron include:—Ladle addition; additions of alloys to the cupola charge in a concentrated form; and the use of pig-iron containing the necessary amount of alloys.

Effect of Chromium

Chromium acts on iron in an opposite manner both to silicon and nickel, in that it increases the chilling tendency of iron and promotes the formation of free carbide, and its hardening effect on iron is partly due to carbide formation. Chromium acts, therefore, in an opposite manner and neutralises the chill-restraining effect of nickel. One part of chromium will approximately neutralise and balance one and a-half part of silicon or three parts of nickel. Chromium acts to build up combined carbon in iron, and it is this feature which renders it useful in conjunction with nickel.

Effect of Molybdenum

The addition of molybdenum to cast iron has been more pronounced recently than ever before, and will go on increasing. The mechanical properties are improved, the tensile strength and the transverse strength even with 0.5 per cent. added. Molybdenum refines the graphite, diminishes grain size, and sorbitises the pearlite; hence it has a favourable influence on mechanical properties. This improvement is not only produced in unalloyed iron, but also in irons alloyed with nickel or chromium, or both. Molybdenum is easily added to the spout or ladle in the form of ferro-molybdenum, the alloy going readily into solution in the iron, although many people prefer to use molybdenum pig to make up the charge.

Austenitic Cast Iron

Molybdenum has also been added with advantage to another recent addition to alloy cast irons, which is a nickel cast iron having an austenitic structure. The charge is made up of a suitable base iron, together with nickel-copper-chromium pig. The approximate range of composition of this special alloy is as follows:—Total carbon, 2.50 to 3.00; silicon, 1.25 to 2.00; sulphur, 0.04 to 0.12; phosphorus, 0.04 to 0.85; manganese, 1.00 to 1.50; copper, 5.00 to 7.00; nickel, 12.00 to 16,00; and chromium, 1.50 to 4.00 per cent. This austenitic iron has very good corrosion-resisting, heat-resisting and non-magnetic properties. The tensile strength is about the same as ordinary cast iron, its elongation is measurable, and is usually between 1.5 and 2.5 per cent. It also has the great advantage of a machinability equal to that of phosphor-bronze. The consistency of a good grain structure under varying rates of cooling is also retained, which is distinctly useful in castings of intricate design.

Conclusion

The use of alloy additions to cast irons has offered not only a method of improving castings so as to fit them for the more rigorous service expected to-day, but has also opened up new fields for iron castings by offering to the engineer such new types of metal as the martensitic and austenitic types obtained by the use of the higher alloy additions. The problems met in automobile engineering are so many and diverse in character that all the various types of cast irons are finding application in one component or another.

It has been shown that small additions are of importance in assisting production by improving strength, density, pressure tightness and machinability. Such improvement is welcome in connection with many designs of cylinder blocks, heads, pistons and numerous other components which, owing to varying section and complex design, present problems due to unsoundness or hardness in machining. In studying the ever-present problem of wear, it has been found that alloy cast irons in the pearlitic, martensitic or austenitic conditions, all have some contribution to offer in improved service; the martensitic type obtained by heat treatment offering, perhaps, the greatest hope for the future. The austenitic iron is of special interest where castings possessing high expansion are required to work in conjunction with aluminium alloys.

* A short Paper contributed to the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen, Mr. G. T. Lunt presiding.

Cast Iron for Cylinder Blocks

ROBERT CASS, writing in a recent issue of "Machinery," states that after a long period of development work on cast iron, the White Motor Company arrived at an analysis which is claimed gives an increase of many thousands of miles of service compared with the cast irons formerly used in the automotive industry. The composition is (per cent.): Si, 1.8 to 2.0; Mn, 0.45 to 0.60; sulphur, 0.12 max.; phosphorus, 0.15 to 0.25; Ni, 0.25 to 0.50, and Cr, 0.40 to 0.70. The Brinell hardness varies from 201 to 229 and the scleroscope hardness in the bore is 40. The iron has uniform machining properties and takes a very high finish.

Copper Additions to Grey Cast Iron*

BY J. HIRD.

The use of copper as an alloy addition to cast iron has in the past been confined mainly to the high-alloy content, austenitic cast irons where certain percentages of this element are used to replace nickel in order to cheapen the mixture. Recently more attention has been given to additions of copper alone, and it is thought that in this connection the following experiments carried out by the author may be of interest. A small number of press blank castings were needed of a much heavier section than usual, and attempts to make these sufficiently close grained and sound in the ordinary mixture in use in the foundry were unsuccessful. The weight of castings required did not justify the use of a special mixture, and as a nickel addition was ruled out by price. it was decided to study the effect of a copper addition.

The iron in general use had the following analysis:—Total carbon, 3.2; silicon, 2.75; and phosphorus, 1.0 per cent.; and a copper addition of 2.5 per cent. was made to this iron. It was found that the copper was best added in the form of scrap bar clippings about ½ in. by $\frac{3}{16}$ in., by 4 or 5 in. long, being first heated and put into a hot ladle and the hottest iron available poured on to it. The whole of the copper was dissolved, and losses were shown to be practically nil by analysis.

Test-bars were cast before and after the copper addition, and transverse and tensile tests were carried out. These showed very little difference in strength. The bars with the copper addition showed a slight increase in tensile and a decrease in transverse strength, as follows:—

Without copper-transverse test. Rupture stress tons sq. in.	— 18.5
With copper-transverse test. Rupture stress tons sq. in.	— 17.4
Without copper tensile test. Max. stress tons sq. in.	— 9.36
With copper tensile test. Max. stress tons sq. in.	— 10.4

Notwithstanding the rather discouraging results from the mechanical tests, there was an outstanding difference in the microstructure of the two irons. The unalloyed iron showed a fine pearlitic matrix with considerable amounts of ferrite. The graphite was rather coarse and unevenly distributed. In the alloyed iron, the ferrite was present in much smaller quantities, the matrix being nearly all fine pearlite. The graphite size was slightly smaller, but there was little difference in its distribution. The decrease in ferrite and the matrix of fine pearlite showed that hardening-up of the iron had taken place, and this was confirmed by the Brinell hardness taken with a 3,000-kilogram load using a 10-mm. ball, the figures being as follow:—

	Brinell hardness No.
Iron without copper ..	207
Iron with copper	235

The blanks for presses cast in the alloy iron did not seem to tire so easily under constant blows from the presses, and lasted much longer than castings made in the same class of iron without copper additions. They were close grained and sound, machined up well and took a high polish. It was thought that in closening the grain of the iron, copper was acting in a similar way to nickel, and it was decided to see whether any greater hardening effect could be produced by more rapid cooling of the iron containing a copper addition. Four bars, 1.2-in. dia. and 24 in. long, were cast, two in ordinary

(*Concluded on page* 322.)

* A short Paper contributed to the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen, Mr. G. T. Lunt presiding.

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This Week's News in Brief

Trade Talk

The Greenock Dockyard Company, Limited, has received an order for a large cargo steamer, which will be 470 ft. long and will carry a deadweight of 10,500 tons.

The employees of T. Walmsley & Sons, Atlas Forge, Bolton, were granted a holiday on Jubilee day with gifts to adult employees of 10s. and to boys of 5s.

Falkirk Dean of Guild Court has passed plans for the erection of a new enamelling shop at the foundry of the Grahamston Iron Company, Limited, at a cost of £1,250.

The Vulcan Foundry, Limited, Newton-le-Willows, has received an order for twelve locomotive boilers for Palestine, to the order of the Agents for the Crown Colonies.

The Staveley Iron & Coal Company, Limited, are to supply Edinburgh Town Council with about 600 tons of 16-in. dia. cast-iron pipes, lined centrifugally with fine concrete.

The Caledon Shipbuilding & Engineering Company, Limited, Dundee, has received an order for a passenger vessel, which will be 218 ft. overall and will have a service speed of 14 knots.

A private company is being formed in Tipperary for the establishment in the town of a foundry which, it is stated, will give regular employment to a score or more workmen. Mr. Dan Breen, a prominent member of the Free State Government, is interested in the venture.

A military band, consisting entirely of men drawn from the engineering works of R. A. Lister & Company, Limited, of Dursley (Glos), has been the first works military band to broadcast. While many industrial firms run brass bands in association with their works, Lister's, so far as is known, is the only firm in the country with a military band.

Many employees of the Singer Manufacturing Company, Limited, at Kilbowie works, who recently saw much of their work being transferred to Italy and the prospect of more going to France as the result of the operation of tariffs, have been cheered by the announcement that the company have decided to transfer their entire factory in New York to Clydebank.

British Industries House Engineering Section has arranged a display of films, accompanied by commentaries, to be held on May 22 and 29, 1935, between the hours of 5 and 7 p.m. The films are being shown by the courtesy of Acetylene & Welding Consulting Bureau, Limited, London, British Oxygen Company, Limited, London, and Murex Welding Processes, Limited, London.

A new furnace was blown in on May 4, capable of producing 2,000 tons of pig-iron a week. It is the new blast furnace built by Colville's Limited, at the firm's Clyde Iron Works, Tollcross, Glasgow. This furnace, the building of which is the first of its kind in Scotland, has an output capacity equal to eight pre-war furnaces. If it is successful, another two furnaces of a similar type will be installed.

The new Steel Products, Limited, factory, recently opened at Carlow, is the only one of its kind in the Irish Free State turning out the blank for the raw-steel strip. Up to the present all blanks have had to be imported for the production of razor blades. It is the intention of the company to turn their attention in the near future to the manufacture of other steel commodities, such as hacksaws.

Plans have been completed for the establishment at Limerick of a works for the manufacture of nuts, bolts, screws and nails, and a company will shortly be registered with a capital of £125,000 under the title of Irish Wire Products, Limited. An important adjunct will be a machine-tool shop in which all fine machinery can be overhauled, a facility which should be of the greatest advantage to the Free State.

Sir Auckland Geddes, speaking at the annual meeting of the Copper Development Association, said that one of the leading water companies had used copper throughout their new building for water supplies, for heating pipes, and also for sanitation pipes. A very large modern block of flats had used copper pipes up to 4-in. dia. for its "one-pipe" sanitation, and thereby saved space, complication and cost.

At the annual general meeting of the West of Scotland Association of Foremen Engineers and Draughtsmen the following officers were elected for the forthcoming session:—President, Mr. R. McCarroll, of the Singer Manufacturing Company, Limited, Clydebank; vice-presidents, Mr. Thomas Paxton, of Messrs. Denny Bros. & Company, Limited, Dumbarton, and Mr. Charles Currie, of Messrs. Barclay Curle & Company, Limited, Glasgow.

Members of the Manchester Association of Engineers are invited, by courtesy of the directors of the Lancashire Steel Corporation, Limited, to visit the works of the Lancashire Steel Corporation at Irlam, on Tuesday, May 21. Members should assemble at the offices, near the main entrance to the works, at 2.30 p.m. Those who intend to take part are requested to inform the secretary, Mr. T. Makemson, St. John Street Chambers, Deansgate, Manchester, 3, as soon as possible, and not later than Thursday, May 16, 1935.

Ardrossan Dockyard Company, Limited, have established two records within a month. On April 4 the largest motor coastal vessel in Great Britain was launched from their yard, and on May 2 a Diesel paddle tug, the first of her type to be built in Great Britain, took the water there. The new vessel, the "Khabour," has been built to the order of Messrs. Lynch Bros., London, for the Euphrates & Tigris Steamship Navigation Company, Limited, London. She has been designed for shallow-draft river service in the East.

The directors of the Grahamston Iron Company, Limited, Falkirk, agreed to grant a Jubilee bonus to all their employees of ten shillings for those over 21 years of age; 7s. 6d. for those between 18 and 21 years of age, and 5s. for all under 18 years. Messrs. Jones & Campbell, Limited, Torwood Foundry, Larbert, have granted similar bonuses, and in addition female employees will receive 7s. 6d. for those over 18 years and those under 18 will receive 5s. By a mutual agreement between the firms concerned, all the foundry workers of Denny & Dunnipace districts, other than those on an upstanding wage and any who were specially required to work on May 6 have received an "*ex-gratia* payment" according to the following scale:—Male employees 21 years and over, 8s.; 18 to 21 years of age, 4s.; under 18 years of age, 2s.; female employees 18 years of age and over, 4s.; under 18 years of age, 2s.

Company Reports

Park Gate Iron & Steel Company, Limited.—Dividend of 3 per cent. for the year ended March 31 last.

William Dixon, Limited.—Profit for year to February 28 last, £50,657; brought in, £6,553; dividend of 5 per cent.; carried forward, £9,410.

Glenfield & Kennedy, Limited.—Final dividend on the ordinary shares of 7 per cent., making 10 per cent., less tax, for the year ended March 31.

Hopkinsons, Limited.—Profit, after provision for all revenue charges, including depreciation, but before providing for income tax, £63,878; brought in £2,483; preference dividend for the year, £18,987; provision for income tax, £18,467; to general reserve, £5,000; dividend on the ordinary shares of 5 per cent., £13,562; carried forward, £10,345.

Stewarts and Lloyds, Limited.—Profit for 1934, after charging debenture interest and before providing for depreciation, £1,004,982; depreciation, £300,000; written off debenture issue expenses, £82,125; brought in, £158,125; interim dividends on the preference shares, £51,537; to income-tax reserve, £140,000; to special reserve for contingencies, £175,000; dividends for half-year ended December 31, 1934, on the 6 per cent. cumulative first preference, 10 per cent. cumulative second preference, and 5 per cent. cumulative third preference shares, £51,537; dividend for year of 1s. per share on the deferred shares and equivalent rate on the liaison deferred shares, £203,504; carried forward, £159,402.

Correspondence

If "Regular Reader," Manchester, who wrote to the Editor on the subject of "Complete Foundry Problems," will forward his name and address, his letter will have attention.—[Editor.]

Personal

Mr. Roland Dunkerly has resigned his position as comptroller of the United Steel Companies, Limited, to become director and general manager of Quilt Manufacturers, Limited, of Manchester. Mr. Dunkerly is a recognised authority on budgetary control and cost accountancy.

Mr. John McAllister has been appointed secretary to the Lion Foundry Company, Limited, Kirkintilloch. Mr. McAllister was presented with a bookcase and a canteen of cutlery by the staff of Messrs. Hurst, Nelson & Company, Limited, Motherwell, where he graduated from office-boy to assistant secretary.

Mr. John T. Batey, managing director of the Hebburn shipyard of Messrs. R. & W. Hawthorn, Leslie & Company, Limited, was re-elected President of the North-East Coast Institution of Engineers and Shipbuilders at the concluding meeting of the session in Newcastle last Friday. This will be Mr. Batey's second year of office.

Mr. M. M. Gillespie, M.I.E.E., of Gillespie & Beales (Norfolk Street, Strand, London, W.C.2) has recently been appointed to the board of Messrs. J. Browett Lindley (1931), Limited, of Letchworth, Herts. For many years Mr. Gillespie was a director of Browett Lindley & Company when the factory was situated at Patricroft, Manchester, and during this period he was closely associated with the development of gas and oil engines, and gas and air compressors. Prior to this, Mr. Gillespie occupied important positions with a number of leading electrical concerns, notably the British Westinghouse Company and Macintosh Cable Company, Limited.

Will

Kidd, John Edward, iron merchant, managing director of John Kidd & Sons, Limited, of Salford, chairman of the English Stockholders (Iron and Steel) Association, who died on January 27 last, aged 54 years ... £10,899

Obituary

Mr. Reginald Burch, manager of Messrs. Moorwoods, Limited, Harleston Ironworks, Sheffield, died recently.

Mr. John Anderson, well known in Scottish iron-foundry circles, died on Sunday at Falkirk. He was for many years cashier with the Gowanbank Iron Company, Falkirk.

Mr. William Bland, aged 58 years, formerly a foreman in the carding machine department at Messrs. Samuel Walker's foundry in Radcliffe, Lancs, and since then employed at Messrs. Bradbury & Saunders' works, Radcliffe, died recently.

Contracts Open

South Africa, May 24.—3,555 3¼-in by 9-ft. cast-iron pipes, for the Union Tender and Supplies Board. The Department of Overseas Trade. (Reference G.Y. 15,086.)

Taxal.—Providing, laying and jointing about 3,330 yds. 4-in. dia. iron pipes, with fittings, for the Macclesfield Rural District Council. Messrs. Brady & Partington, Market Street, Chapel-en-le-Frith. (Fee £3, returnable.)

Bucklow, May 20.—For the Bucklow Rural District Council:—(1) Supply and delivery of about 22,615 yds. 3-in. spun-iron and 4,644 yds. 2-in. dia. cast-iron water mains and specials; (2) supply and delivery of valves, hydrants, etc. Mr. H. V. Shaw, 26, Station Buildings, Altrincham. (Fee £2 2s. returnable.)

The Department of Industrial Administration of Loughborough College, Leicestershire, has decided to provide a short series of week-end courses for engineering executives dealing with costing, rate-fixing and progress control. The course starts on May 10 and finishes with the week-end of May 24. The instructional fee for any single week-end course is £2 2s., whilst board and residence at a college hostel for a week-end course is £1 11s. 6d.

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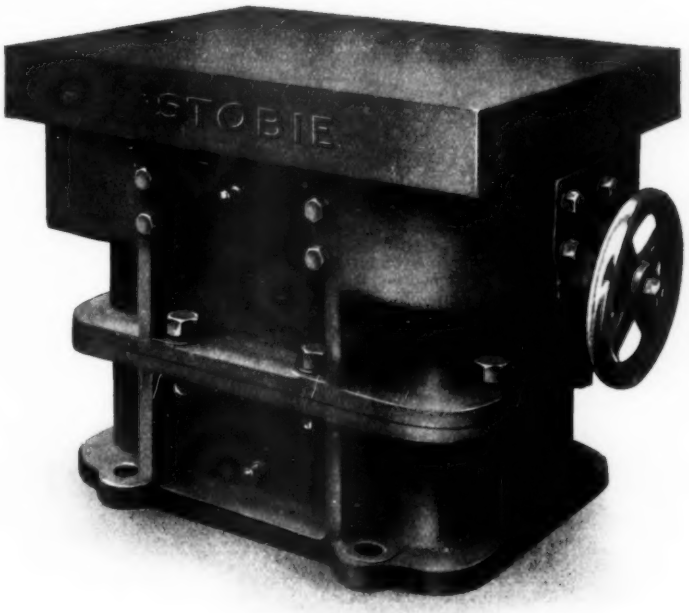

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Raw Material Markets

A high rate of production is being maintained at the iron and steel works in this country, although in some quarters orders are being worked off more quickly than they are being replaced. To a certain extent, consumers hesitated to buy until the result of the negotiations with the Continental Steel Cartel was known. Now that this uncertainty has been removed, orders are flowing somewhat more freely, and it is anticipated that a large number of bookings will shortly be made.

Pig-Iron

MIDDLESBROUGH.—Although the demand for foundry iron is somewhat subdued, the output is still restricted to two furnaces, so that stocks are being steadily drawn upon. On the other hand, the output of basic iron is at a very high level. The fixed home quotations in the case of the standard No. 3 G.M.B. foundry grade are as follow:—Delivered in the Middlesbrough area, 67s. 6d.; delivered Durham and Northumberland, 69s. 6d.; delivered Falkirk, 67s. 3d.; delivered Glasgow, 70s. 3d. per ton.

The output of East Coast hematite is being steadily absorbed, and, with indications of a slight expansion in the export trade, future prospects are fairly satisfactory. The controlled figure for No. 1 quality delivered Middlesbrough remains at 69s. per ton.

LANCASHIRE.—The call for deliveries of foundry iron in this area has steadily expanded, and has at least reached the level ruling before the Easter interruption. According to some Midland ironmasters, the demand is now somewhat in excess of what it was twelve months ago. New buying is still on a relatively quiet scale, however. For delivery in the Lancashire zone, Derbyshire and Staffordshire brands of No. 3 foundry iron, and also Lancashire makes equal to Derbyshire, continue to be quoted on the basis of 74s. per ton, with Northamptonshire material at 72s. 6d.. Scottish No. 3 foundry at from 81s. 6d. to 82s. 6d., West Coast hematite at around 78s. 6d., and East Coast hematite at from 75s. to 76s. per ton, according to grade.

MIDLANDS.—The current demand for supplies of foundry iron is on a fairly satisfactory scale, although activity in the light-castings trade is still below expectations. There is plenty of ordinary No. 3 iron available. In some cases the furnaces are putting iron into stock, as the demand is not equal to the output. The controlled figures delivered Birmingham and Black Country stations are 67s. 6d. per ton for Northants No. 3 and 71s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, subject to a small rebate to large users. In respect to pig-iron for the general engineering and jobbing trades, in the aggregate a fair tonnage is now being consumed. There remains no control on the various qualities which come into this district from divers points. Scottish No. 3 and other low-phosphorus iron is offered at from 85s. to 87s. 6d. per ton, medium-phosphorus iron 72s. to 80s., and special refined iron for engine and other work from £5 7s. 6d. to £7 per ton delivered the Midlands.

SCOTLAND.—The Glasgow pig-iron market has been more active lately, although foundry iron is still the quietest section. There is no change in the official minimum prices at 70s. per ton, f.o.t. furnaces, for No. 3, with 2s. 6d. extra for No. 1. The light-castings foundries remain generally busy, although in one or two cases new orders would be welcomed. Where Cleveland iron is required, the official quotations remain at 67s 3d. f.o.t. Falkirk and 70s. 3d. f.o.t. Glasgow, other English foundry irons being obtainable at 1s. 3d. per ton less.

Coke

Business in foundry coke has been on a limited scale lately, consumers showing little interest. Quotations for deliveries in the Birmingham district remain at:—Best Durham coke, 36s. to 40s.; other qualities, down to 34s.; Welsh coke, 34s. to 43s. 6d. per ton.

Steel

Steady employment is being maintained in the steel trades, and the outlook is definitely encouraging. A high rate of activity is called for at many producing works in order to satisfy the demand for deliveries against running contracts. Although makers are not making new additions to their order-books at the rate they would desire, new business is steadily broadening out. The inquiry for structural steel materials is reported to be very good. Semi-finished steel remains in steady demand. Quotations are generally unchanged.

The increased rates of Customs duties which came into force as from March 26 have been temporarily reduced for a period of three months from May 8 to the rates previously in force. This follows the agreement reached between representatives of the British and Continental steel industries for the limitation of imports into this country.

Scrap

There is a steady demand for cast-iron scrap in the Cleveland area, prices being 52s. 6d. to 53s. for ordinary foundry cast-iron scrap and 55s. for good machinery quality in convenient sizes. In the Midlands, heavy machinery cast-iron scrap is offered at 55s. to 57s. 6d. and good heavy metal at 50s., both delivered works. By comparison, dealing in scrap iron in South Wales is very quiet, quotations averaging 51s. to 53s. 6d. for heavy cast iron in large pieces and furnace sizes and 52s. 6d. to 55s. for good cast-iron machinery scrap in foundry sizes. In Scotland, on the other hand, there is a good inquiry from the ironfoundries, and machinery cast-iron scrap, in pieces suitable for their cupolas, is 56s. 6d., with ordinary cast-iron scrap to same specification 52s. 6d.

Metals

Copper.—The fact that the international plan for the restriction of copper supplies is now in operation has had a stiffening effect upon the market. The repercussions of the scheme will probably not be felt for some months, but this has proved no deterrent to speculators and dealing in standard metal has been active.

At the same time, industrial consumption of copper in this country is maintained at a high level. Considerable quantities of the red metal have also gone to the Continent recently, particularly to the armament factories.

Official quotations were as follow:—

Cash.—Thursday, £32 1s. 3d. to £32 3s. 9d.; Friday, £32 5s. to £32 7s. 6d.; Tuesday, £32 11s. 3d. to £32 12s. 6d.; Wednesday, £32 12s. 6d. to £32 13s. 9d.

Three Months. — Thursday, £32 10s. to £32 12s. 6d.; Friday, £32 13s. 9d. to £32 15s.; Tuesday, £33 to £33 1s. 3d.; Wednesday, £33 to £33 1s. 3d

Tin.—Trading in tin has been of a limited character, few industrial buyers being in the market. A heavy premium has had to be paid for prompt supplies as compared with three months forward. In addition, heavy premiums have been asked for Straits and Banca supplies.

Dealers on the London Metal Exchange walked out of the tin "ring" yesterday as a protest against the artificial conditions ruling the market, which have resulted in an acute shortage of spot metal. The latter was nominally quoted at £6 per ton more than tin for delivery three months ahead—a reversal of the usual conditions. It is apparently hoped to persuade the International Tin Committee to release greater supplies.

Daily price movements:—

Cash.—Thursday, £225 to £225 5s.; Friday, £225 5s. to £225 10s.; Tuesday, £224 15s. to £225 5s.; Wednesday, £224 to £225.

Three Months.—Thursday, £219 5s. to £220; Friday, £219 15s. to £220; Tuesday, £219 5s. to £219 10s.; Wednesday, £218 5s. to £218 10s.

Spelter.—The firm tone in this market reflects the satisfactory European demand for spelter at the present time. The possibility of a revision of the present import-duty arrangements is another "bull" point.

Day-to-day prices:—

Ordinary.—Thursday, £13 15s.; Friday, £14; Tuesday, £13 17s. 6d.; Wednesday, £14.

Lead.—The uncertainty in connection with the proposed modification of the present duty on imports of foreign lead continues to affect the market, and rather more speculative activity has been witnessed. At the same time, there is quite a fair demand for ordinary industrial use.

In Germany, the use of lead for certain commercial purposes, *e.g.*, in connection with house plumbing and motor-car manufacture, has been prohibited, in view of the "dangerously" low level to which lead stocks have fallen.

Official quotations:—

Soft Foreign (Prompt).—Thursday, £13 2s. 6d.; Friday, £13 3s. 9d.; Tuesday, £12 18s. 9d.; Wednesday, £13 1s. 3d.

Copper Additions to Grey Cast Iron

(*Concluded from page* 318.)

iron out of the same ladle, and two in iron out of the same tap with 3 per cent. copper added.

One bar of ordinary iron and one bar with the copper in were knocked out of the sand immediately they were cast. They were gently placed on the floor, and an air blast from a compressed-air pipe was directed on them until they were at room temperature. These four bars were tested for transverse strength. The results were between 19 and 21 tons per sq. in., the two air-cooled bars being the strongest.

Brinell figures taken on the bars showed a very definite indication of an increased hardness of the air-cooled copper bar over the other bars, and were as follow:—

	Brinell No.
Ordinary iron air-cooled	241
Copper iron air-cooled	269
Ordinary iron left in mould till cold	223
Copper iron left in mould till cold ..	241

The air-cooled bar containing copper was definitely harder to file than the mould-cooled bar, this being equally true for the centre of the bar as well as the outside.

Chill tests taken in "V" chill blocks, ¾ in. thick, and making a casting 4 in. long, 2 in. deep and 1 in. wide at the top, showed about ⅛ in. white at the point with unalloyed iron, whilst the 3 per cent. copper-alloyed iron showed no chill at all. On filing these two chill blocks on the grey portion, the one with 3 per cent. copper in was definitely the harder to file, yet would have been expected to be the softer owing to the complete absence of white chilling.

From these experiments it would appear that small additions of copper to a common grey iron give harder and closer metal, while at the same time reducing the tendency to chill. To obtain the maximum hardening effect, the castings should be knocked out hot. It should be mentioned here that the whole of the copper went into solution in the iron, although, according to some published literature, the solubility of copper in cast iron is lower than the amounts used in these experiments.

Falkirk Bath for the King's Jubilee House

One of the baths for the house that is the Silver Jubilee gift of the Royal Warrant Holders to His Majesty the King, is, as has already been announced in these columns, being supplied by Messrs. M. Cockburn & Company, Limited, Gowanbank Iron Works, Falkirk, to the order of the Leeds Fireclay Company, Limited, Royal Warrant Holders. The design is unique. Made, of course, of cast iron, and beautifully enamelled in pale green, it has the deep front introduced in bath manufacture a year or two ago, and which has become the most popular type among high-class luxury baths. A novel feature is that the bath itself is set within the oblong at an angle which naturally affords a longer bathing space, and provides, at the same time, a broad outer ledge which can be used as a seat, and ample space at the other side for soap, sponges and other bathing equipment. The outside panel is set back in such a way that it is possible to stand close to the bath without the feet coming in contact with it. The inlet and overflow are of special design, and are of chrome-plated brass, while there are serviceable hand grips on each side, also of chrome-plated brass. The taps will be fitted in the wall.

XUM

Sterling

MOULDING BOXES

ARE THE GREATEST ECONOMY
YOU CAN INTRODUCE INTO
YOUR FOUNDRY

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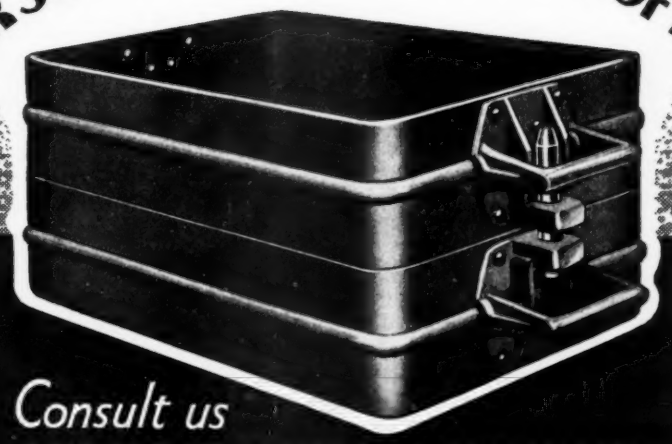
THEY SPEED UP PRODUCTION
PRODUCE BETTER CASTINGS
SAVE UNNECESSARY LABOUR

OVER 30 STANDARD DESIGNS OF BOXES



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AND LET US SOLVE YOUR MOULDING BOX PROBLEMS—

STERLING FOUNDRY SPECIALTIES LTD
BEDFORD
LONDON OFFICE: 13 VICTORIA STREET · WESTMINSTER · S.W.1

RAW MATERIALS—PRICE LIST

(Wednesday, May 8, 1935)

COPPER

	£ s. d.
Standard cash	32 12 6
Three months	33 0 0
Electrolytic	36 0 0
Tough	34 10 0
Best selected	35 0 0
Sheets	60 0 0
India	46 10 0
Wire bars	36 10 0
Ingot bars	36 10 0
H.C. wire rods	39 5 0
Off. av. cash, April	31 5 4⅞
Do., 3 mths., April	31 13 9
Do., Sttlmnt., April	31 5 3
Do., Electro, April	35 1 10½
Do., B.S., April	34 13 0⅝
Do., wire bars, April	35 8 6
Solid drawn tubes	9¾d.
Brazed tubes	9¾d.
Wire	6¼d

BRASS

Solid drawn tubes	9d.
Brazed tubes	11d.
Rods, drawn	8¾d.
Rods, extd. or rlld.	4¼d.
Sheets to 10 w.g.	7½d.
Wire	7¾d.
Rolled metal	7d.
Yellow metal rods	4¼d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£ s. d.
Standard cash	224 0 0
Three months	218 5 0
English	224 10 0
Bars	226 7 6
Straits	233 0 0
Australian (nom.)	—
Eastern	228 12 6
Banca	232 0 0
Off. av. cash, April	223 13 8½
Do., 3 mths., April	219 18 0¾
Do., Sttlmt., April	223 13 9

SPELTER

	£ s. d.
Ordinary	14 0 0
Remelted	13 17 6
Hard	11 0 0
Electro 99.9	16 12 6
English	15 2 6
India	12 15 0
Zinc dust	17 5 0
Zinc ashes	3 0 0
Off. aver., April	13 0 2¼
Aver. spot, April	12 17 9¾

LEAD

	£ s. d.
Soft foreign ppt.	13 1 3
Empire (nom.)	14 3 9
English	15 0 0
Off. average, April	12 6 10⅞
Average spot, April	12 4 7½

ALUMINIUM

Ingots	£100 to £105
Wire	1/1 to 1/9 lb.
Sheet and foil	1/2 to 2/9 lb.

ZINC SHEETS, &c.

	£ s. d.
Zinc sheets, English	23 10 0
Do., V.M. ex-whse.	23 12 6
Rods	27 15 0

ANTIMONY

	£ s. d.
English	76 0 0 to 77 0 0
Chinese, ex-whse., (nom.)	64 0 0
Crude	—

QUICKSILVER

	£ s. d.
Quicksilver	11 7 6 to 11 17 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
23/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£15 15 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	31 10 0
4/6% car.	21 15 0
6/8% car.	21 10 0
8/10% car.	21 10 0
Ferro-chrome—	
Max. 2% car.	34 0 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70%, carbon-free	9¾d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	5/- to 5/6 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£10 15 0 to £11 5 0
76/80% packed	£11 15 0 to £12 5 0
76/80% export	(nom.) £9 15 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d
Finished bars, 18% tungsten	2s. 9d

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 7/32 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅜ in.	3d. lb.
Do., under ¼ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

South Wales—	£ s. d.	£ s. d.
Heavy steel	2 15 0	to 2 16 0
Bundled shrngs.		2 7 6
Mixed iron and steel	2 10 0	to 2 11 6
Heavy cast iron	2 10 0	to 2 13 6
Good machinery	2 12 6	to 2 15 0
Cleveland—		
Heavy steel		2 12 6
Steel turnings		1 15 0
Cast-iron borings		1 5 0
Heavy cast iron	2 12 6	to 2 13 0
Heavy machinery		2 15 0
Midlands—		
Light cast-iron scrap		2 7 6
Heavy wrought iron		2 17 6
Steel turnings, f.o.r.		1 14 0
Scotland—		
Heavy steel		2 10 0
Ordinary cast iron		2 12 6
Engineers' turnings		1 19 6
Cast-iron borings	1 17 6	to 1 19 0
Wr'ght-iron piling	2 15 0	to 2 17 6
Heavy machinery		2 16 6

London—Merchants' buying prices, delivered yard.

	£ s. d.
Copper (clean)	27 0 0
Brass	18 0 0
Lead (less usual draft)	11 10 0
Tea lead	8 10 0
Zinc	9 0 0
New aluminium cuttings	66 0 0
Braziery copper	23 0 0
Gunmetal	25 0 0
Hollow pewter	155 0 0
Shaped black pewter	110 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	70/-
Foundry No. 3	67/6
,, at Falkirk	67/3
,, at Glasgow	70/3
Foundry No. 4	66/6
Forge No. 4	66/6
Hematite No. 1	69/-
Hematite M/Nos.	68/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	72/6
,, d/d Birm.	84/6
Malleable iron d/d Birm.	115/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	67/-
,, No. 3 fdry.	71/-
Northants forge	63/6
,, fdry. No. 3	67/6
,, fdry. No. 1	70/6
Derbyshire forge	67/-
,, fdry. No. 3	71/-
,, fdry. No. 1	74/-
Scotland—	
Foundry No. 1, f.o.t.	72/6
,, No. 3, f.o.t.	70/-
Hem. M/Nos. d/d	71/-
Sheffield (d/d district)—	
Derby forge	64/6
,, fdry. No. 3	68/6
Lincs forge	64/6
,, fdry. No. 3	68/6
E.C. hematite	81/6
W.C. hematite	83/6
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	74/-
Staffs fdry. No. 3	74/-
Northants fdry. No. 3	72/6
Cleveland fdry. No. 3	74/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	82/6
Clyde, No. 3	82/6
Monkland, No. 3	82/6
Summerlee, No. 3	82/6
Eglinton, No. 3	82/6
Gartsherrie, No. 3	82/6
Shotts, No. 3	82/6

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)	9 12 6	to 9 15 0
Nut and bolt iron	7 10 0	to 8 0 0
Hoops	10 10 0	and up.
Marked bars (Staffs) f.o.t.	12 0 0	
Gas strip	10 10 0	and up.
Bolts and nuts, ¾ in. × 4 in.	14 2 6	and up.
Steel—		
Plates, ship, etc.	8 15 0	to 8 17 6
Boiler plts.	9 5 0	to 9 7 6
Chequer plts.		10 7 6
Angles		8 7 6
Tees		9 7 6
Joists		8 15 0
Rounds and squares, 3 in. to 5½ in.		9 7 6
Rounds under 3 in. to ⅜ in. (Untested)		8 12 0
Flats—8 in. wide and over		8 12 6
,, under 8 in. and over 5 in.		8 17 6
Rails, heavy	8 5 0	to 8 10 0
Fishplates	12 5 0	to 12 10 0
Hoops (Staffs)		9 7 0
Black sheets, 24g. (4-t. lots)		10 10 0
Galv. cor. shts. (,,)		13 0 0
Galv. flat shts. (,,)		13 10 0
Galv. fencing wire, 8g. plain		14 10 0
Billets, soft	5 10 0	and up.
Billets, hard	6 17 6	to 7 2 6
Sheet bars	5 2 6	to 5 10 0
Tin bars	5 2 6	to 5 7 6

PHOSPHOR BRONZE

	Per lb. basis.
Strip	9¾d.
Sheet to 10 w.g.	10¾d.
Wire	11¾d.
Rods	10¾d.
Tubes	13¾d.
Castings	12d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7¼
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	20.26
No. 2 foundry, Valley	18.50
No. 2 foundry, Birm.	14.50
Basic, Valley	18.00
Bessemer	20.76
Malleable, Valley	18.50
Grey forge, Valley	18.00
Ferro-mang. 80%, seaboard	85.00
O.-h. rails, h'y, at mill	36.37½
Billets	27.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.80
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.70
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.60
Plain wire	2.30
Barbed wire, galv.	3.00
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 30/-
,, furnace	19/- to 20/-
Durham foundry	19/- to 22/-
,, furnace	16/6 to 17/9
Midlands, foundry	—
,, furnace	—

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14	per box	18/2 to 19/2
,,	28×20	,,	36/4 to 38/4
,,	20×10	,,	26/- to 26/3
,,	18¾×14	,,	18/6 to 18/9
C.W.	20×14	,,	15/3 to 16/3
,,	28×20	,,	32/9 to 33/3
,,	20×10	,,	22/9 to 23/9
,,	18¾×14	,,	15/9 to 16/9

SWEDISH CHARCOAL IRON & STEEL

	£ s. d.	£ s. d.
Pig-iron	£6 0 0	to £7 0 0
Bars-hammered, basis	£16 0 0	to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0	to £16 0 0
Blooms	£10 0 0	to £12 0 0
Keg steel	£30 0 0	to £31 0 0
Faggot steel	£18 0 0	to £23 0 0
Bars and rods dead soft, st'l	£10 0 0	to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£	s.	d.	
May	2 ..	32	1	3	dec. 2/6
,,	3 ..	32	5	0	inc. 3/9
,,	7 ..	32	11	3	,, 6/3
,,	8 ..	32	12	6	,, 1/3

Standard Tin (cash)

		£	s.	d.	
May	2 ..	225	0	0	dec. 20/-
,,	3 ..	225	5	0	inc. 5/-
,,	7 ..	224	15	0	dec. 10/-
,,	8 ..	224	0	0	,, 15/-

Spelter (ordinary)

		£	s.	d.	
May	2 ..	13	15	0	dec. 2/6
,,	3 ..	14	0	0	inc. 5/-
,,	7 ..	13	17	6	dec. 2/6
,,	8 ..	14	0	0	inc. 2/6

Zinc Sheets (English)

		£	s.	d.	
May	2 ..	23	10	0	inc. 15/-
,,	3 ..	23	10	0	No change
,,	7 ..	23	10	0	,, ,,
,,	8 ..	23	10	0	,, ,,

Electrolytic Copper

		£	s.	d.	
May	2 ..	35	10	0	No change
,,	3 ..	35	15	0	inc. 5/-
,,	7 ..	36	0	0	,, 5/-
,,	8 ..	36	0	0	No change

Tin (English ingots)

		£	s.	d.	
May	2 ..	225	5	0	dec. 20/-
,,	3 ..	225	15	0	inc. 10/-
,,	7 ..	225	5	0	dec. 10/-
,,	8 ..	224	10	0	,, 15/-

Spelter (Electro, 99.9 per cent.)

		£	s.	d.	
May	2 ..	16	7	6	dec. 2/6
,,	3 ..	16	12	6	inc. 5/-
,,	7 ..	16	10	0	dec. 2/6
,,	8 ..	16	12	6	inc. 2/6

Lead (English)

		£	s.	d.	
May	2 ..	15	5	0	No change
,,	3 ..	15	5	0	,, ,,
,,	7 ..	15	0	0	dec. 10/-
,,	8 ..	15	0	0	No change

AVERAGE MONTHLY PRICES OF CLEVELAND No. 3 PIG-IRON.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1895	34 7	34 4	34 4	34 8	35 6	35 2	36 1	37 1	38 10	38 6	37 11	37 6	36 3
1896	37 3	38 4	38 7	38 1	37 4	37 4	36 11	36 11	37 11	39 2	40 5	40 5	38 3
1897	41 2	40 4	40 5	39 2	39 7	40 9	39 6	40 5	41 7	42 5	41 5	40 4	40 7
1898	40 9	40 8	40 6	40 0	40 7	39 11	40 4	41 11	43 0	44 11	49 1	44 3	42 0
1899	46 10	47 11	47 9	49 10	55 11	62 10	71 6	65 9	67 7	68 8	70 0	66 9	60 5
1900	67 10	68 10	73 10	76 2	74 2	68 6	69 3	71 4	70 9	67 8	63 6	53 6	68 9
1901	48 0	46 6	45 8	45 5	45 10	44 7	44 6	45 3	45 3	45 3	43 6	43 1	45 3
1902	43 11	46 7	46 9	47 11	48 10	49 7	50 9	52 1	53 6	52 9	50 9	47 11	49 3
1903	47 3	48 9	51 10	49 0	46 1	46 2	46 7	46 8	45 7	43 6	42 10	41 11	46 4
1904	42 3	42 7	43 3	44 7	44 0	42 10	42 9	43 3	43 1	43 9	46 1	48 7	43 11
1905	48 11	48 0	49 6	50 1	51 5	45 6	45 9	47 5	48 8	52 11	52 9	53 3	49 6
1906	53 9	50 1	48 1	48 8	50 2	50 3	50 6	53 0	54 6	56 8	58 6	62 4	53 6
1907	60 4	56 6	54 10	56 0	61 1	58 1	57 8	57 8	55 7	54 8	50 8	50 0	56 2
1908	48 5	49 3	51 7	51 10	51 6	51 2	50 0	51 4	52 0	49 8	49 4	48 11	50 8
1909	48 10	48 1	46 9	47 9	48 4	48 9	48 6	50 5	51 3	51 11	51 2	50 7	49 4
1910	51 10	51 3½	51 7½	50 10	49 10	49 2	48 10	49 8½	49 3½	49 7½	49 6½	49 10	50 4
1911	49 11½	49 2½	48 5	46 11	46 4	46 6	46 11½	47 4	47 0	46 7	47 4½	48 1	47 7
1912	50 0	49 5½	51 1½	53 7½	54 4	55 1	57 5½	64 6½	61 7½	66 8½	67 8	68 0	58 5½
1913	66 11½	63 8½	64 8	67 1½	66 3	56 9½	56 3½	55 8	55 4	53 0	50 1	50 4	58 10
1914	50 11	51 5½	51 0½	51 4½	51 6	51 6½	51 5	52 3	51 5	50 1	50 3	53 0	51 4½
1915	55 7	56 6	61 0	66 7	65 2	66 10	65 4	66 0½	65 3	65 11	69 10½	75 7½	65 7
1916	80 2	91 6	87 4½	86 10	82 6	82 6	87 6	87 6	87 6	87 6	87 6	87 6	85 10
1917	87 6	87 6	87 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	95 0	99 3
1918	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0
1919	95 0	95 0	95 0	95 0	152 6	160 0	160 0	160 0	160 0	160 0	160 0	160 0	137 8
1920	175 0	175 0	187 6	200 0	208 0	217 6	217 6	221 0	225 0	225 0	225 0	225 0	209 3
1921	222 6	195 0	150 0	126 0	120 0	120 0	120 0	136 3	127 0	120 0	110 0	100 0	137 4
1922	92 6	90 0	90 0	90 0	90 0	90 0	89 0	87 3	92 6	92 6	92 6	91 3½	90 7½
1923	94 6	108 9	125 6	129 4½	128 5	136 0	128 1½	121 11	97 1½	97 0	100 0	100 0	110 6½
1924	99 10	97 3½	91 9	93 9	91 9	89 10½	87 9	85 0	82 5½	80 2½	81 9	81 9	88 7½
1925	80 4½	78 10½	78 0	78 3	76 0	73 10½	71 7½	69 10½	68 1½	66 7½	66 0	66 10½	72 10½
1926	69 4½	70 0	70 0	70 0	72 6	75 10½	86 7½	90 0	93 10½	117 10	120 0	99 0	86 3
1927	85 0	83 1½	81 0	80 0	73 9	70 0	70 0	68 9	67 6	67 6	66 10½	65 0	78 2½
1928	65 0	65 0	65 6	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	65 9½
1929	66 0	66 9	67 0	68 1½	69 5	71 10½	72 9	72 6	72 6	72 6	72 6	72 6	70 4½
1930	72 6	72 6	70 0	67 6	67 6	67 6	67 6	64 6	63 6	63 6	63 6	63 6	66 11½
1931	59 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 7
1932	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6
1933*	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6
1934*	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	66 10½
1935*	67 6	67 6	67 6	67 6	—	—	—	—	—	—	—	—	—

* Delivered Middlesbrough area. Prior to 1933, prices were f.o.t. furnaces.

WILLIAM JACKS & COMPANY,
WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.
13, RUMFORD STREET, LIVERPOOL.

PIG IRON

REGISTERED TRADE MARK
LIMPET

All grades FOUNDRY, HEMATITE, BASIC, SPECIALS, &c.

NON-FERROUS METALS

COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

WILLIAM JACKS & COMPANY,
CENTRAL CHAMBERS, 93, HOPE ST., GLASGOW, C.2.
ZETLAND ROAD, MIDDLESBROUGH.

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(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

FIRST-CLASS Foreman required to take charge of Wet-Enamelling Shop at large works. Must not only be excellent disciplinarian, able to get the best out of the shop, but must have a thorough knowledge, theoretical and practical, of enamelling procedure.—Apply Box 236. Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOUNDRY Foreman required to take charge of a foundry specialising in repetition "Y"-alloy castings, both sand and die. Only first-class men with thorough practical experience will be considered.—Apply Box 244, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

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